REMARKS

AND

EXPERIMENTS

ON DIFFERENT PARTS

OF THE

PROCESS OF BREWING;

PARTICULARLY

ON THE CONTINUED APPLICATION

OF A

BOILING HEAT

DURING THE

OPERATION OF MASHING.

OXFORD,

Printed by Nathaniel Bliss,

FOR R. BLISS, AND R. BLISS, JUN.

AND SOLD BY F. AND C. RIVINGTON; CADELL AND DAVIES;
W. MILLAR; LONGMAN, HURST, REES, & ORME;
VERNOR, HOOD, & SHARPE; J. HARDING;
AND MESSRS. RICHARDSONS, LONDON,

1807.

TO THE READER.

SO many Treatises on Brewing have been already published, and some of these enter so minutely into the detail of the process, that it would be superfluous to add to their number except with the hope of adding also to the information they contain: whether the remarks and statements made in the following pages are to be considered as of any interest, beyond what degree of novelty may belong to them, is left to the judgment of those who have more experience than the Author; and who can therefore better form an opinion whether they are likely to lead to any practical improvement: the hope that they may possibly lead to such an end is the best apology for publishing them.

REMARKS,

&c.

THE principal and only essentially necessary substances employed in the composition of Beer, or Malt Liquor in general, are water, malt, and hops: and the ultimate object of the Brewer is to combine with the water as much as possible of the saccharine and other soluble matter of the malt, together with the bitter and aromatic particles of the hops. Hot water effects this purpose more speedily, and to a greater extent, than cold; and, when thus impregnated with the soluble matter of the malt and hops, constitutes what is called Wort: in which the saccharine matter, principally, renders the mixture capable of fermentation; the bitter and aromatic particles prevent that fermentation from proceeding too far.

The process of Brewing is commonly conducted nearly in the following manner: in describing which a reference is principally made to the brewing of table beer from fresh malt; that is, from malt which has not been already used for brewing ale. The quantity to be brewed may be taken as a barrel, or thirty-six gallons, from two bushels and a half of malt; and the dimensions of the vessels, &c. may be supposed to correspond with those used in a moderate family; the copper, for instance, holding thirty gallons.

A quantity of boiling water being poured into a vessel, called a Mash-Tun, is suffered to remain there till it has cooled to a temperature rarely if ever exceeding 180 of Fahr.: the malt, previously broken in a mill so that each grain shall have been divided into two or three parts, is then thrown into the water; and, by means of an instrument called an Oar, is stirred about in, and thoroughly mixed with it: this mechanical agitation of the malt and water, technically called Mashing, is kept up for about a quarter of an hour; by which the

malt is more effectually brought into contact with the water, and a greater proportion of its soluble matter extracted. After this the mash-tun is covered over, in order to retain as much heat as possible, and the whole is suffered to remain undisturbed for an hour and half, or two hours. At the end of that time, the water thus impregnated with the extracted particles of the malt (in which state it is sometimes called Sweet-Wort, sometimes simply Wort,) is drawn off into another vessel. The quantity of water used in this first mashing is about twenty-five gallons; of which not above fifteen are obtained, the rest being absorbed by the malt, with the exception of a small quantity carried off by evaporation.

This first wort being drawn off from the malt, a fresh portion of hot water is thrown into the mash-tun, at a temperature varying, according to the judgment of the brewer, from 180 to 212 of Fahr^{t}: the process of mashing is repeated during the space of ten minutes; and, the tun being again covered, the whole is suffered to remain for about an hour; at the end of

which time a second wort is drawn off. The quantity of water used in this second mashing is about fifteen gallons; and, the malt having already retained as much water as is sufficient to saturate it, the whole amount of the fifteen gallons is afterwards recovered from the mash-tun.

A fresh quantity of hot water, about twelve gallons, is now added to the malt; and the mixture, being mashed for a few minutes, is suffered to remain in the tun for half an hour, or an hour, or more, in order to form a third wort.

In the mean time a part of the two first worts is poured into the copper, with a pound and half or two pounds of hops, and boiled for an hour, or an hour and half: after which it is strained through a sieve into another vessel. The third wort is now drawn off from the mash-tun; and, being mixed with the remaining part of the first and second, is boiled, for an hour or more, with the hops used in the former instance.

The three worts are then distributed into

shallow vessels, called Coolers, and suffered to remain there till they have nearly sunk to the temperature at which it may be thought right to promote fermentation: they are then collected into one vessel, called a Fermenting Vat; and, by the addition of about a quart of yeast, that process is soon produced, which converts the wort into beer.

This short description of the common method of brewing table beer will be sufficient for the purpose of introducing the following remarks, which have a reference to particular parts of that process; and, indeed, of the process of brewing in general. With respect then to the water employed in brewing, that which is soft is by many recommended in preference to that which is hard; and as the solvent power of water, as well as its softness, is generally in proportion to the degree of its purity, there would be reason for that preference were extreme accuracy required; but, when we consider that hard water scarcely ever holds in solution more than what would amount to one thousandth part of its weight, and that

in many cases a great proportion of this is deposited during boiling; and, when we again consider that the wort even from which the strongest ale is to be produced might be still further impregnated with the soluble matter of the malt and hops, there does not appear any reasonable ground for the preference; or, if there is, it does not hold good in practice. The just preference which is given to soft water in another economical process, namely Washing, affords indeed a plausible ground for a preference in this also: but the objections to the use of hard water rest really on very different grounds in the different cases, as they who are at all acquainted with the principles of chemistry well know: it may be sufficient for the present to observe, that in the case of brewing the force of the objection is lessened in proportion as the quantity of water is increased; while in the case of washing the force of the objection is increased in proportion to the increase in the quantity of the water.

It may be considered therefore as of very little consequence whether rain, or river, or

spring water be employed; nor is it of more consequence whether, in the process of mashing, the hot water is taken before or after boiling, provided it is of that temperature which may be determined on as fit for the process. The direction therefore commonly given of pouring the boiling water into the mash-tun, there to remain till the steam rises in so small a quantity that a person may see his face in the water below, is only an empirical mode of ascertaining that the temperature is now proper for the addition of the malt, without, as it is technically called, "setting the goods:" the meaning of which term may perhaps be understood from the following explanation.

Water at or near the boiling point very readily converts any farinaceous substance, like malt, into a paste; and this paste is impervious, or nearly so, to liquids in general: but, as it is the object of mashing to give the water an opportunity of dissolving the saccharine particles of the malt, the effect must necessarily be in a great measure prevented, if the surface of each particle of the malt, by being converted into a paste, pre-

vents the water from penetrating into the body of it: the common language therefore on this occasion is very expressive, which says, that the too great heat of the water closes the pores of the malt.

In the process of brewing, as already described, it is seen that the first wort being withdrawn from the malt, a second and a third are obtained: and the reason of mashing with three separate portions of water instead of with the whole quantity at once, is partly because, in the latter case, a great portion of a richer wort would be retained by the grains (so the mass is called which remains in the mash-tun after all the wort has been drawn off from it), which now is more completely washed out by the repeated addition of fresh water; and partly because the water itself in divided quantities extracts more abundantly the soluble parts of the malt, than the same quantity of water used at once would be able to do.

The process of mashing, if conducted properly, is supposed to extract as much of the soluble matter of the malt as can be

extracted with economy: in the subsequent process of boiling the wort with the hops two ends are answered; for at the same time that the bitter and preservative quality of the hops is united with the wort, the wort itself is increased in strength: that is, its bulk being reduced by evaporation, which merely carries off the watery particles, the original quantity of saccharine matter &c. remains, diffused through a smaller space than it was before.

The distribution of the wort into coolers, after it has been boiled with the hops, is evidently for the purpose of lowering its temperature as quickly as possible; and this is done not only to save time, but also to prevent its growing sour, which otherwise, especially in warm weather, would often happen. For the same reasons also yeast is added; the process of fermentation not absolutely depending on, but being very materially accelerated by the addition of, that substance.

With respect to the nature of fermenta-

tion itself, such observations as have occurred in the course of the Experiments hereafter described will be mentioned in the latter part of this Treatise.

The foregoing account is, in a general view, applicable to the common method of brewing malt liquor; in referring to which it appears, that the reason of the different parts of the process is easily deducible from a slight consideration of the joint properties of water and heat. Since therefore it is evident that, in mashing, Hot water is used in preference to Cold, because it more powerfully and in a shorter time extracts the soluble part of the malt; and, that the reason for limiting the degree of heat is only to prevent the malt from being converted into a paste, which in a great measure would exclude the water from acting upon it; it appears fair in reasoning to suppose, that, if an increased heat could be applied without producing that effect, the soluble part of the malt would be still more abundantly, or at least more quickly, extracted: and it was the hope of answering

this end which in the present instance led to the experiment of gradually heating the malt and water together to the boiling point. For, as every intermediate degree of heat, between the common temperature and that usually employed in mashing, would extract some of the soluble matter of the malt, it appeared probable that each particle would be so far softened and loosened in its texture, by the time it had reached this heat, that an increase of temperature would not have the effect which it has when applied at once to the cold and unsoftened malt: and this reasoning is supported in some measure by practice; for after the first mashing the rule of not applying water above a certain temperature is very frequently disregarded.

This inference appears so obvious, that, although it is not taken notice of in any of the publications on the subject of brewing, it very probably has occurred to many persons; and the practice to which it leads has, perhaps, not been adopted because in opposition to general opinion. However this

may be, the experiment has fully succeeded in as many as twenty instances; and, at the same time that this method of brewing produces a kind of beer altogether not inferior to that obtained by the common method, from similar proportions of malt and hops, it possesses the additional advantage of being attended with some less trouble and loss of time, and perhaps some less expense.

It now remains therefore to give an account of the Experiments that were made for the purpose of proving the truth of the foregoing reasoning, accompanied with such remarks as seem applicable to the several results.

In public breweries the intrinsic value of the wort, with respect to its saccharine contents &c., is estimated by means of an hydrometer; which, by shewing the difference in specific gravity between the wort and simple water, gives the means of calculating the absolute weight of saccharine matter, &c. contained in any given quantity of the former.

An instrument of this kind was tried in the present experiments; but, owing to some fault either in itself or in the construction of the table of calculations which accompanied it, it was not found sufficiently accurate; and therefore it was thought better to make a calculation of the proportion of soluble matter extracted from a given quantity of malt and hops by taking the absolute weight of a given quantity of wort made from them. This, though not so scientific a method as the other, has, from the nature of the apparatus, the advantage of being less liable to error.

For this purpose a glass vessel was employed (having a narrow cylindrical neck), which when perfectly dry weighed 1844 gr^s. The balance by which this vessel was weighed would easily turn with half a grain when 4000 grains were in each scale; and a fine line being drawn with a diamond round the cylindrical part, it might easily be filled with water to that mark several times in succession, without the variation of a grain in the weight of the contents.

That quantity of distilled water, Gr.
at 55 of Fahr^{t}, weighed 2600

The same quantity of water of the river Isis, at Oxford, weighed so nearly the same at the same temperature, that the difference could not be satisfactorily estimated.

The same quantity of pump-water of Oxford, at the same temperature, weighed 2602
but after having been boiled for ten minutes, and then reduced to the original temperature, it weighed 2600.5

The difference in the weight, between the fresh and the boiled water, is owing to the deposition of that earthy matter by which the inner surfaces of vessels, used for boiling such water, are said to be furred; and as in this state its weight is to that of distilled water as 2600 to 2600.5, the difference is no more than $\frac{1}{5200}$th part; which is too small to deserve notice.

In weighing then the above quantity of a given wort it is clear that whatever was the excess above 2600 grains was due to a part of the soluble matter that had been extracted from the malt and hops, with the difference already stated of $\frac{1}{5200}$th part; and then the proportion in any other quantity of the same wort was easily found by calculation from the following data.

The cubic contents of an English wine pint are	Cub. Inch^s. 28.875
And the weight of an English wine pint of distilled water, at 55 of Fahr^t, is . . .	Gr^s. 7310.428125
The cubic contents of an English beer pint are	Cub. Inch^s. 35.5
And the weight consequently, at 55 of Fahr^t, is	Gr^s. 8924.41875

But, since 2600 : 1 :: 8924.41875 : 3.43246, it appears that for every grain which this quantity of a given wort weighed above 2600 grains there is to be allowed as the

proportional increase

	Gr'.
In a pint of the same wort . . .	3.43246
In a gallon	27.45968
And in a barrel (36 gallons) .	988.54848

From these data the following table was constructed: in which the column on the left hand marks the difference in weight between a quantity of water weighing 2600 grains, and the same quantity of a given wort; the columns on the right hand shew the proportional increase in the gallon and barrel. That increase, multiplied by the number of gallons or barrels of wort obtained, shews the absolute weight of the soluble matter extracted from any given quantity of malt and hops; which is all the brewer desires to learn from the use of the common hydrometer, the place of which instrument was in the following experiments supplied by the apparatus already described.

TABLE

OF THE

Weight of Saccharine Matter, &c. in a GALLON *and* BARREL *of a given Wort, according to the Difference in Weight between a Quantity of Water weighing* 2600 gr^s., *and the same Quantity of that Wort.*

Increase in Weight of the given quantity of WORT by Grains.	Proportional Increase in the GALLON and BARREL, calculated by Avoird. Weight.					
	GALLON.			BARREL.		
Gr^s.	lb.	Oz.	Gr^s.	lb.	Oz.	Gr^s.
1 .	0	0	27.45	0	2	113.54
2 .	0	0	54.90	0	4	227.08
3 .	0	0	82.35	0	6	340.62
4 .	0	0	109.80	0	9	16.66
5 .	0	0	137.25	0	11	130.20
6 .	0	0	164.70	0	13	243.74
7 .	0	0	192.15	0	15	357.28
8 .	0	0	219.60	1	2	33.32
9 .	0	0	247.05	1	4	146.86
10 .	0	0	274.50	1	6	260.40
20 .	0	1	111.50	2	13	83.30
30 .	0	1	385.00	4	3	343.70
40 .	0	2	223.00	5	10	166.60
50 .	0	3	59.00	7	0	427.00
60 .	0	3	334.50	8	7	249.90
70 .	0	4	170.50	9	14	72.80
80 .	0	5	6.50	11	4	333.20
90 .	0	5	282.00	12	11	156.10
100 .	0	6	118.00	14	1	416.00
200 .	0	12	236.00	28	3	394.50

In order to prevent a troublesome repetition of words, it may be convenient here to observe, that, in conducting the following Experiments, the specific gravity of each wort was taken at the temperature of between 55 and 60 of Fahr^{t}.; and the quantity was calculated at the same temperature: for convenience also the specific gravity of each wort will be signified by a reference to the numbers in the left hand column of the foregoing table. Thus, if the sp. gr. of a wort is said to be 100, it is to be understood that a quantity of that wort equal in bulk to a quantity of water weighing 2600 gr^{s}. exceeded the weight of that water by 100 gr^{s}.; which is in the proportion of 6oz. 118gr^{s}. to the gallon, and 14lb. 1oz. 412.5gr^{s}. to the barrel.

Exp^{t}. 1.

Sixteen gallons of river-water, together with a pound of hops, and $\frac{8}{9}$ of a bushel of malt ground smaller than usual, were put into a copper, the capacity of which was twenty gallons: the whole was gradually heated till it boiled, and after it had re-

mained at the boiling point for half an hour it was strained through a hair sieve.

	lb.	oz.	grs.
The sp. gr. of this wort was 164. The quantity of it was 8 gallons. It therefore contained of saccharine matter, &c.	5	2	123

The malt and hops were returned into the copper: fourteen gallons of water being then added to them, the whole was made to boil; and immediately after boiling was strained.

	lb.	oz.	grs.
The sp. gr. of this wort was 50. The quantity of it was 12 gallons. It therefore contained of saccharine matter, &c.	2	5	270
The malt and hops were now boiled a third time, and gave 6 gallons of a wort, the sp. gr. of which was 24: that quantity contained therefore &c.	0	9	15

	lb.	oz.	grs.
The process was again repeated, and produced 6 gallons of a wort, the sp. gr. of which was 12 : the 6 gallons therefore contained &c. . . .	0	4	225
Thus the whole weight of soluble matter extracted was . . .	8	5	196
and the quantity used being $\frac{8}{9}$ of a bushel, the proportion in the quarter, or 8 bushels, is	75	1	14

The first and second worts being mixed together at the temp. of 82 of Fahr., a pint of yeast was added to them, and they were immediately put into an 18 gallon barrel.

The fermentation of the liquor proceeded in the usual way for several days; and the beer produced was at the end of three weeks tolerably transparent, and of a good taste.

EXP^{t}. II.

Fifteen gallons of pump-water were gradually heated to the boiling point, with $\frac{8}{9}$ of a bushel of malt ground down nearly to

the state of flour; and the mixture was kept at the boiling heat during an hour and a half.

	lb.	oz.	grs.
The sp. gr. of the first wort was 164. The quantity of it was 9 gallons. It contained therefore of saccharine matter, &c.	5	12	248

The malt was again boiled with a fresh portion of water for an hour and a half.

	lb.	oz.	grs.
The sp. gr. of the second wort was 72. The quantity of it was 9 gallons. It therefore contained &c.	2	8	278
The sum of the soluble contents of the two worts is . . .	8	5	89
And the quantity of malt used being $\frac{8}{9}$ of a bushel, the proportion in the quarter, or 8 bushels, is	74	14	359

The two worts being mixed, and the

sp. gr. of the mixture taken, which was 118, they were boiled for three quarters of an hour with a pound of hops: enough boiling water was added to make up the quantity lost by evaporation, and the sp. gr. was again taken: it was now 118.5.

A part of this wort, mixed at the temp. of 88 with a pint of yeast, was poured immediately into a fifteen-gallon barrel.

Fermentation proceeded in the usual manner, and at the end of the third day the sp. gr. of this beer was 44.

At the end of the eighteenth day the sp. gr. was 34.

On the twenty-fourth day the sp. gr. was only 29: the beer was very transparent, dark coloured, and of a good taste.

EXP^{T}. III.

Fifteen gallons of river-water were boiled

for four hours with a pound of hops and $\frac{8}{9}$ of a bushel of malt, as finely ground as in the last Exp^{t}.

	lb.	oz.	grs.
The sp. gr. of the first wort was 200. The quantity of it was 6 gallons. It contained therefore &c.	4	11	103

The malt and hops were again boiled with pump-water for two hours.

	lb.	oz.	grs.
The sp. gr. of the second wort was 103. The quantity was 7 gallons. It contained therefore &c.	2	13	90

Four gallons of cold water were now poured upon the malt and hops; and having been mashed with them for ten minutes were immediately strained off.

	lb.	oz.	grs.
The sp. gr. of this third wort was 67. The quantity was 4 gallons. It contained therefore &c.	1	0	356

	lb.	oz.	grs.
The quantity extracted from $\frac{8}{9}$ of a bushel of malt in this instance amounted to . .	8	9	111
The proportion therefore in the quarter, or 8 bushels, is .	77	3	124

The sp. gr. of the three worts mixed together was 129. A pint of yeast was added to the mixture; which at the temp. of 82 was poured into a fifteen-gallon barrel. Fermentation proceeded moderately; and on the twentieth day the sp. gr. was 35.

Expt. iv.

Sixteen gallons of pump-water were boiled for an hour and half with a pound of hops and $\frac{8}{9}$ of a bushel of malt, finely ground; and the mixture was constantly stirred together during the whole of the time.

	lb.	oz.	grs.
The sp. gr. of the first wort was 150. The quantity was 9 gallons. It contained therefore &c.	5	4	280

The malt and hops were again boiled and stirred together during two hours.

	lb.	oz.	grs.
The sp. gr. of the second wort was 65. The quantity was 9 gallons. It contained therefore &c.	2	4	308
The sum of the soluble contents of the two worts is . . .	7	9	151
And the quantity of malt used being $\frac{8}{9}$ of a bushel, the proportion in the quarter, or 8 bushels, is	68	4	46

The sp. gr. of the mixture of the two worts was 108; to which at the temp. of 80 a pint of yeast being added, the fermentation was carried on in an open tub: and at the end of ten hours the beer was put into a fifteen-gallon barrel: at the end of sixty hours from the addition of the yeast the sp. gr. was 40.

Exp^{t}. v.

Fifteen gallons of pump-water were boiled with $\frac{8}{9}$ of a bushel of malt finely ground, and three quarters of a pound of hops, for two hours; and the mixture was constantly stirred during the whole of the time.

	lb.	oz.	grs.
The sp. gr. of the first wort was 160. The quantity of it was 6 gallons. It contained therefore &c.	3	12	90

The malt and hops were again boiled &c. with fresh water for two hours.

	lb.	oz.	grs.
The sp. gr. of the second wort was 100. The quantity was 10 gallons. It contained therefore &c.	3	14	305

	lb.	oz.	grs.
The quantity extracted from $\frac{8}{9}$ of a bushel in this instance weighed	7	10	395

The proportion therefore in the quarter, or 8 bushels, is . .	lb.	oz.	grs.
	69	2	55

Exp^{t}. vi.

Sixteen gallons of river-water were boiled for two hours with a pound of hops and $\frac{8}{9}$ of a bushel of malt, ground in the common manner, and the mixture was constantly stirred during the whole of the time.

The sp. gr. of the first wort was 148. The quantity was 8 gallons. It contained therefore &c.	lb.	oz.	grs.
	4	10	109

The malt and hops were again boiled &c. with a fresh portion of water for two hours.

The sp. gr. of the second wort was 65. The quantity was 7 gallons. It contained therefore &c.	lb.	oz.	grs.
	1	12	239

	lb.	oz.	grs.
The quantity extracted in this instance from $\frac{8}{9}$ of a bushel of malt weighed	6	6	349
The proportion therefore in the quarter, or 8 bushels, is .	57	13	78

Exp^{t}. vii.

Fifteen gallons of water were boiled for three hours, and stirred at the same time, with $\frac{8}{9}$ of a bushel of malt ground in the usual manner: six gallons of cold water were then added and the whole was made to boil &c. for two hours. Six gallons of wort were then strained off, and nine gallons of cold water were added to the malt and hops: these were mashed together for half an hour, and then strained into the former six gallons.

The sp. gr. of this wort was 98.

	lb.	oz.	grs.
The quantity thus obtained was 16 gallons. It contained therefore &c.	6	2	150

	lb.	oz.	grs.
And this being the quantity extracted from $\frac{8}{9}$ of a bushel, the proportion in the quarter, or 8 bushels, is	55	5	37

A pint of yeast was added to these sixteen gallons, at the temp. of 78, in an open tub; and at the end of twenty-four hours the beer was put into a fifteen-gallon barrel. At the end of seventeen days its sp. gr. was 43, and it was tolerably transparent.

Expt. viii.

Fifteen gallons of water were boiled, and constantly stirred for an hour, with $\frac{8}{9}$ of a bushel of malt, ground in the common manner, and three quarters of a pound of hops. The whole was then thrown into a mash-tun, and six gallons of wort were drawn off and returned into the copper: ten gallons of cold water were then added to the malt and hops, and being mashed with them for ten minutes were drawn off and added to the six gallons in the copper: these sixteen

gallons were made to boil, and in the mean time seven gallons of cold water were added to the malt and hops and mashed with them for an hour; after which they were drawn off and added to the quantity contained in the copper; which was made to boil during three hours and a half.

The sp. gr. of this wort was 110.

	lb.	oz.	grs.
The quantity was 15½ gallons,			
It therefore contained &c. .	6	10	396
which being the quantity extracted from $\frac{8}{9}$ of a bushel, the proportion in the quarter, or 8 bushels, is	60	2	64

A pint of yeast was added to this wort at the temp. of 88, the temp. of the surrounding atmosphere being 52; and three hours afterwards fermentation was going on very favourably. This beer was put into a barrel twenty-four hours after the addition of the yeast: at the end of ten days it was very transparent, and of a good taste; and its sp. gr. was 50: at the end of eighteen days its sp. gr. was 43.

Exp. ix.

Fifteen gallons of water were boiled and constantly stirred for an hour and half, with $\frac{8}{9}$ of a bushel of malt ground in the common manner, and three quarters of a pound of hops: the whole was then thrown into a mash-tun, and the wort was drawn off.

The sp. gr. of this wort was 152.

	lb.	oz.	grs.
The quantity was 9 gallons.			
It contained therefore &c. .	5	5	337

This wort being returned into the copper, a fresh quantity of cold water was mashed with the malt and hops for about ten minutes: a second wort consisting of nine gallons was then drawn off, and added to that in the copper: in the same manner a third wort was obtained amounting to three gallons, which was added to the two first worts; and the whole was boiled together for two hours.

	lb.	oz.	grs.
The sp. gr. of the wort thus obtained was 108. The quantity of it was 15 gallons. It contained therefore &c. . .	6	5	251
which being the quantity extracted from $\frac{8}{9}$ of a bushel, the proportion in the quarter, or 8 bushels, is . . .	57	2	71

A pint of yeast was added to this wort at the temp. of 90; and within two hours it was fermenting rapidly and favourably: the temp. of the surrounding air at the same time was 40. Fermentation proceeded in the usual manner and at the end of ten days the sp. gr. of this beer was 48; and it was as transparent as beer is usually.

Expt. x.

Fifty gallons of pump-water were boiled &c. for an hour, with four bushels of malt ground in the common manner, and three pounds of hops.

	lb.	oz.	grs.
The sp. gr. of the first wort was 188. The quantity was 26 gallons. It contained therefore &c.	19	2	195

Thirty-six gallons of cold water were now added to the malt and hops in the copper, and the whole was made to boil &c., and then strained off.

	lb.	oz.	grs.
The sp. gr. of the second wort was 86. The quantity was 36 gallons. It contained therefore &c.	12	2	38

Six gallons of cold water were thrown on the malt and hops in the copper; the whole was mashed together for ten minutes, and a third wort was then drawn off.

	lb.	oz.	grs.
The sp. gr. of this third wort was 30. The quantity was 9 gallons. It contained therefore &c.	1	0	402
The quantity extracted in this instance from four bushels weighed	32	5	197

	lb.	oz.	grs.
The proportion therefore in the quarter, or 8 bushels, is . .	64	10	394

The sp. gr. of the mixture of the three worts was 115; three pints of yeast were added to it at the temp. of 95, the temp. of the surrounding air being 60. During fermentation there was a very violent effervescence in the liquor, but the bubbles, which rose in great numbers, were not accompanied with that white tenacious froth which is generally present; and the temp. of the liquor remained sensibly above that of the surrounding air for forty-eight hours; the beer at the same time being very thick: at the end of ninety-six hours the appearance of the fermentation became more favourable; the temperature of the beer sunk to that of the surrounding air; and the liquor itself became somewhat clearer.

At this time its sp. gr. was 44.

In the three following instances the process of brewing was carried on in the common manner, and in the two first of them

by persons professionally in the habit of brewing.

Exp^{t}. xi.

In this process the operation of mashing was applied three times to twenty bushels of malt ground in the usual manner.

The capacity of the copper was four barrels (144 gallons.)

The sp. gr. of the first wort was	195
of the second . . .	120
of the third . . .	54

Part of the first and second worts were boiled with ten pounds of hops: after which the third wort and the remaining part of the first and second were boiled with the same hops.

The whole process occupied fifteen hours.

The sp. gr. of the mixture of the three worts, after having been boiled with the hops, was 135. The quantity was 8 barrels (288 gallons). It contained therefore &c.	lb. 152	oz. 8	gr. 119

	lb.	oz.	grs.
which being the quantity extracted from 20 bushels, the proportion in the quarter, or 8 bushels, is	61	0	46

Exp^{t}. xii.

In this process the operation of mashing was applied three times to twenty-eight bushels of malt ground in the usual manner.

Two coppers were employed: the capacity of one was nine barrels (324 gallons); of the other, five barrels (180 gallons).

The sp. gr. of the first wort was .	220
of the second . . .	118
of the third . . .	50

Part of the first and second worts was boiled with twenty-one pounds of hops: the third wort and the remaining part of the first and second were then boiled with the same hops.

The whole process occupied sixteen hours.

The sp. gr. of the mixture of the three worts, after having been boiled with the hops, was 117.

	lb.	oz.	grs.
The quantity was 12 barrels (432 gallons). It contained therefore &c.	198	4	154
which being the amount of the quantity obtained from 28 bushels, the proportion in the quarter, or 8 bushels, is .	56	10	169

At the end of ninety-six hours the sp. gr. of this beer was 51.

Expt. xiii.

Twelve gallons of water, at the temp. of 170, were mashed for ten minutes with $\frac{8}{9}$ of a bushel of malt: at the end of an hour and a half the wort was drawn off.

	lb.	oz.	grs.
The sp. gr. of this wort was 154. The quantity of it was 6 gallons. It contained therefore &c.	3	9	408

Eight gallons of water, at the temp. of 170, were then added to the malt in the mash-tun, and were mashed with it for ten minutes: at the end of twelve hours the wort was drawn off, and was at that time of the temp. of 100.

	lb.	oz.	grs.
The sp. gr. of this wort was 100. The quantity was 6 gallons. It contained therefore &c. .	2	5	270
A third wort, the sp. gr. of which was 50, consisted of 4 gallons, and contained &c.	0	12	236
The quantity in this case extracted from $\frac{8}{9}$ of a bushel of malt was	6	12	39
The proportion therefore in the quarter, or 8 bushels, is .	60	12	351

THE account of the foregoing experiments has been collected from notes that were accurately taken during the several processes. Many more experiments have been made on the plan of the first ten, and apparently with similar success; but, as the management of them was committed in a great measure to the care of others, the similarity of the results can only be inferred in a general way.

In calculating the quantity of the several worts very ample allowance was made for the effect of expansion as depending on temperature, and great care was taken in weighing them; so that the results here given are certainly not above what they ought to be: and in each of the experiments, except the eleventh and twelfth, both the quantity of the malt made use of and of the wort obtained was measured by single gallons. In all the calculations also,

also, as well of the* table as of the several experiments, the same care was taken to lessen rather than increase the estimates; though it is believed that the error thus occasioned does not amount in any instance to more than a few grains. In all those instances where $\frac{8}{9}$ of a bushel are stated to have been used, it was originally intended to use a bushel: the intention failed from not having considered the difference in the space occupied by equal weights of ground and whole malt. In order to ascertain the degree of this difference a Winchester bushel was exactly filled with whole malt, which was then put into a mill and ground in the usual manner: it was received in a sack placed under the mill, and afterwards mea-

* The calculations of the table were made on the supposition (as has been already stated) that the beer-pint of distilled water weighs at 55 of Fahr^{t}. 8924.41875 grs; which number is assumed from a statement, made on the authority of the late Professor Robinson of Edinburgh, that a cubic inch of distilled water weighs, at 55 of Fahr^{t}., 253.175 grs.; wherefore, as the capacity of the beer-pint is 35.25 cub. in., its weight will be (253.175 × 35.25) 8924.41875 grs. Vid. Kerr's Translation of Lavoisier's Elements of Chemistry. Edinb. 1796, 8vo. 3rd edit. Append. p. 585.

sured; but instead of measuring 8 gallons it measured $9\frac{3}{8}$; allowing therefore for the occasional difference in the size of the particles of different parcels of ground malt, as resulting from the use of different mills, the increase in the bulk may be taken generally as at least $\frac{1}{8}$. Nine gallons of malt therefore ground in the common manner are equal to eight gallons, or a Winchester bushel, of whole malt; and as in the foregoing instances only eight gallons of the ground malt were used, the real quantity of malt was $\frac{8}{9}$ of a bushel. When malt is very finely ground the difference is not quite so much: this difference was estimated from a comparison of the different weights of equal measures.

	lb.	oz.	grs.
A gallon of malt ground in the usual manner weighs . .	4	8	0
A gallon of finely ground malt weighs	4	11	260
The weight of 8 gallons of the former is	36	0	0

lb. oz. grs.

The weight &c. of the latter is 37 12 330

lb. oz. grs. lb.

And since 37 12 330 : 36 :: 1 : 0.952453, it follows that the result of each experiment in which the finely ground malt was used must be diminished in the proportion of 1 to 0.952453. The results therefore of the five first experiments, when thus corrected, will be

	lb.	oz.	grs.
Exp. I. . .	71	7	405
Exp. II. . .	71	5	359
Exp. III. .	73	8	240
Exp. IV. . .	65	0	78
Exp. V. . .	65	13	233

The reason of using the malt so finely ground arose from the observation that in the common mode of grinding many grains escape unbroken; and it was found, by an experiment made for the purpose, that the water scarcely acts on these. The stirring of the malt and hops with the water, first mentioned in the fourth Experiment, was found necessary to prevent the malt from burning to the bottom of the copper: this

operation increases the trouble of the process; but, where the malt is not finely ground, it perhaps facilitates the extraction of the saccharine matter.

In reviewing the foregoing experiments it will be seen that the average of the five first, after the correction made in pag. 46, is 69 lb 7 oz. 88 grs.; and that in these instances finely ground malt was used, and the boiling heat was applied twice at least.

In the five next Experiments the average is 59 lb. 128 grs. In these experiments malt ground in the usual manner was employed: in three out of the five indeed the boiling heat was only applied once; which circumstance may be supposed to have contributed towards lessening the average: but in the two instances where the boiling heat was applied twice, the results are not nearly so great as the average of the results in the first five: so that the diminution appears to depend more on

the state of the malt than on the degree of heat applied.

	lb.	oz.	grs.
In the three last Experiments the average is	59	7	334

FROM the second Experiment it appears that the addition of the soluble matter extracted from the hops is too trifling to deserve notice; for a wort, previously impregnated with the saccharine matter &c. of the malt, was only increased in sp. gr., after having been boiled with the usual proportion of hops for three quarters of an hour, from 118 to 118.5: and in another instance, in which a pound of hops was boiled for two hours with fifteen gallons of water, the sp. gr. of the water was only increased from 0.5 to 2, or about 3 ounces, in the barrel: but, were the increase greater, it would be of no signification; since in the common mode of

estimating the specific gravity of worts, the estimate is taken after the addition of the soluble matter of the hops.

It appears, from the first, third, ninth, and thirteenth experiments, that a third boiling, or even simple mashing, extracts an additional quantity of saccharine matter sufficient materially to affect the results: wherefore the quantity obtained in the second, fourth, fifth, sixth, and seventh experiments would have been increased had the operation of boiling or mashing been used a third time, as it was in the other experiments: so that the average given in either instance is to be considered as less than it might have been. But as the highest average here given is below what professional persons have sometimes stated as the average quantity of saccharine matter &c. to be expected from a quarter of malt, it may be satisfactory to produce a statement on this part of the subject from better authority: the following is copied from a * Publication, by a gentleman of the name

* York, 1805. 8vo. 3d edition, page 237.

of Richardson, entitled "The Philosophical Principles of the Science of Brewing."

Malt from the Barley of 1781.

No.	Colour.	Character.	Growth of Barley.	Average Produce of Fermentable Matter.
1	Pale.	Well made.	North Lincolnsh.	82 Pounds.
2	Ditto.	Indifferent.	Ditto.	75 Ditto.
3	Ditto.	Well made.	Norfolk.	72 Ditto.
4	Ditto.	Ditto.	YorkshireWoulds.	82 Ditto.
5	Brown.	Ditto.	Ditto.	78 Ditto.
6	Ditto.	Ditto.	Ware, in Herts.	56 Ditto.

Malt from the Barley of 1782.

No.	Colour.	Character.	Growth of Barley.	Average Produce.
1	Pale.	Well made.	YorkshireWoulds.	62 Pounds.
2	Ditto.	Ditto.	Bremen.	58 Ditto.
3	Ditto.	Ditto.	Norfolk.	67 Ditto.
4	Ditto.	Indifferent.	Ditto.	56 Ditto.
5	Brown.	Well made.	Ware, in Herts.	54 Ditto.

Malt from the Barley of 1783.

No.	Colour.	Character,	Growth of Barley.	Average Produce.
1	Pale.	Well made.	North Lincolnsh.	74 Pounds.
2	Ditto.	Ditto.	Berw^{k}. on Tweed.	63 Ditto.
3	Ditto.	Indifferent.	YorkshireWoulds.	65 Ditto.
4	Ditto.	Well made.	Ditto.	75 Ditto.
5	Brown.	Ditto.	Ditto.	72 Ditto.

By this statement it appears that the value of malt may be very different in dif-

ferent years; for of the examples here produced

	lb.	oz.	grs.
The average for the year 1781 is	74	2	245
1782	59	6	175
1783	69,12		350

It is probable therefore, and it is believed indeed to be the case, that the malt of the present year is below the general average value with respect to the proportion of its saccharine contents. Should there however have been any error in the preceding mode of calculation, which from its simplicity is not likely, it cannot affect the comparative value of the estimates; because the same mode of calculation was adopted in all the instances.

Upon the whole therefore it appears, that the continued application of a boiling heat to the malt certainly occasions no loss with respect to the quantity of saccharine matter extracted; and that the use of finely ground malt, instead of that which has been ground in the usual manner, gives a considerable additional profit. But the ad-

vantage of the method of Brewing here recommended is more evident when the consequent saving of time and labour is considered; in order to estimate which fairly, it will be necessary to enter into a more detailed comparison of the several stages of the common process, and of that recommended in this Treatise.

In the instances of the eleventh and twelfth experiments it is seen, that the time occupied in brewing eight barrels (the capacity of the copper being four barrels) was fifteen hours; and the time occupied in brewing twelve barrels (the joint capacity of the two coppers being fourteen barrels) was sixteen hours: but though the processes were here conducted by persons professionally in the habit of brewing, and the whole apparatus was as well adapted to the purpose as in a public brewery, yet as profit was not the object of those at whose expense the processes were carried on, and therefore the saving of time was not of much consequence, it might be considered hardly fair to use those instances as examples in the following comparison: it is

presumed however, from the nature of the process itself, that even in a public brewery the proportion of time occupied cannot be very different from that mentioned in the first of those instances; and that in this case if the capacity of the copper were eight barrels, and it were intended to brew sixteen barrels of beer, the time necessary for the process would be sixteen hours.

Suppose then with a copper of the same size the same quantity of beer was to be brewed by the method here recommended, the several parts of the process with respect to the time occupied would be as follows:

	hours.
Filling and boiling the copper . . .	$1\frac{1}{2}$
Boiling the first wort	$0\frac{1}{2}$
Drawing off the first wort	$0\frac{1}{4}$
Again filling and boiling the copper .	*$0\frac{3}{4}$
Boiling the second wort	1
Drawing off the second wort . . .	$0\frac{1}{4}$

* It would scarcely be so much; because it has been found by observation that the heat of the malt in the copper raises the temp. of the cold water to 150.

Mashing with a few gallons of cold water for five minutes, and then drawing off the third wort . . . . $0\frac{1}{4}$

$4\frac{1}{2}$

Quantity of wort obtained eight barrels.

Allowing for the removal of the malt and hops from the copper . $0\frac{1}{4}$

hours.

Repeating the former process . . . $4\frac{1}{2}$

$4\frac{3}{4}$

Quantity of wort obtained 8 barrels.

By the above two processes, sixteen barrels of wort may be obtained in $9\frac{1}{4}$ hours; which is not much more than half the time supposed to be employed in a public brewery in obtaining the same quantity: and the expense of and the room occupied by a mash-tun are saved.

It remains to make a comparison of the number of separate operations in the two processes.

In the common process the following are the operations necessarily employed.

Transferring the malt from the sack to the mash-tun 1

Filling and boiling the copper . . . 2

Transferring the hot water from the copper to the mash-tun 3

Mashing; and then transferring the first wort from the mash-tun . . . 4

Again filling and boiling the copper . 5

Again transferring the hot water to the mash-tun 6

Mashing; and then transferring the second wort from the mash-tun . . . 7

Transferring water to the mash-tun for the third mashing 8

Mashing; and then transferring the third wort from the mash-tun. . . 9

Transferring to the copper, and boiling together with the hops, a part of the first and second worts . . . 10

Transferring the wort thus boiled to the cooler 11

Transferring &c. and boiling the third wort and remaining part of the first and second 12

Transferring the wort thus boiled to the cooler 13

In the process recommended in this Treatise the necessary operations are

Transferring the malt and hops to the copper 1

Filling and boiling the copper . . . 2

Drawing off the first wort into the cooler 3

Again filling and boiling the copper . 4

Drawing off the second wort into the cooler 5

Adding a small proportion of cold water, and mashing for five minutes . 6

Drawing off the third wort into the cooler 7

So that the proportion of time and of labour saved, by adopting the latter process, is very nearly one half: the additional profit arising from the use of finely ground malt is common to both. . .

Having stated these advantages it is fair to add that the plan is perhaps more calculated for domestic than for public Brewing; at least it would require the experience of those who are conversant with the subject to make it practicable on a large scale. The objection to its application on such a scale depends in some measure on the space occupied by the malt and hops: on which account, and also on account of the proportion of water retained by the malt, there cannot be drawn off from the copper more than, indeed not quite so much as, half the quantity of its capacity. Thus from a copper capable of holding two barrels (seventy-two gallons), since five bushels of malt and $1\frac{1}{2}$lb of hops would occupy the space of about twenty gallons of water, and each bushel would retain about four gallons, not more than thirty-two gallons would be recovered after each boiling. In brewing table beer this objection is not of much force, because the proportion of malt used is comparatively small: a stronger objection arises from the difficulty of keeping a very large mass of malt in agitation during

the process of heating and boiling the water; though even this probably might be surmounted by adapting to the copper the apparatus which in large breweries is adapted to the mash-tun.

It has already been stated that the beer produced by the preceding method of brewing is altogether not inferior to that which has been brewed in the common way. Of transparency and taste, the senses are sufficiently accurate judges; of its strength, or the quantity of spirit of wine contained in it, a tolerably correct estimate may be formed by comparing the specific gravities before and after fermentation.

In the publication above referred to, the Author says (p. 187.) he has never known the sp. gr. of malt liquor reduced more than in the proportion of $\frac{7}{8}$ of the sp. gr. of the wort from which it was made; in general not more than in the proportion of $\frac{3}{4}$; and sometimes scarcely more than $\frac{1}{2}$. There appears reason to conclude from another part of the same publication, that the reduction

is usually somewhat short of $\frac{2}{3}$: for in p. 381. there is this expression, " observing that a " wort of 30 lb per barrel was frequently " attenuated to 10 lb;" which seems to imply that the reduction was generally not so much as two thirds. These data will enable the reader to judge of the effect of fermentation, as to this point, in the foregoing experiments.

In the second experiment the sp. gr. was reduced from 118.5 to 29; or in the proportion of . 0.76

In the third &c. from 129 to 35; or &c. 0.73

In the fourth &c. from 108 to 40; or &c. 0.63

In the seventh &c. from 98 to 43; or &c. 0.57

In the eighth &c. from 110 to 43; or &c. 0.61

In the ninth &c. from 108 to 48; or &c. 0.56

In the tenth &c. from 115 to 87;	
or &c.	0.68
The average of these numbers is	0.6485

In three of the seven instances here mentioned the reduction of the sp. gr. was in the proportion of above $\frac{2}{3}$; but even the average is very nearly as high as $\frac{2}{3}$; and when it is considered that the fermentation had not proceeded in any instance beyond the twenty-fourth, and on the whole not beyond the sixteenth day, the results, as compared with the statements just now made, sufficiently prove that the fermentation of the beer here brewed produced the usual proportion of spirit of wine.

A few observations have occurred on the nature of fermentation, during the progress of the experiments related in this Treatise; which, though not new perhaps to those who have reflected scientifically on the subject, may yet be acceptable to others.

When yeast is mixed with wort at a proper temperature, a froth is very soon formed on the surface of the liquor; consisting of

numerous air bubbles that are continually rising from the bottom of the vessel in which the process is carried on. At this time the liquor is turbid and has scarcely any degree of transparency; but as the process advances a gradual deposition of the opaque particles takes place; and the liquor becomes comparatively transparent, and specifically lighter: the change in the appearance &c. is known to be accompanied with the production of a quantity of spirit of wine proportional to the quantity of saccharine matter originally contained in the wort: and hence beer which has been brewed from a great proportion of malt is not only richer in taste but more inebriating than beer which has been brewed from a small proportion. But as spirit of wine is specifically lighter than even distilled water, and much more so therefore than any wort, those opaque particles, which were easily suspended by the wort before fermentation, now readily subside in it; and the beer consequently becomes transparent.

The transparency of beer is sometimes

promoted by means of isinglass, or similar substances, technically known by the name of "Finings;" the action of all of which is merely mechanical, and only produces transparency without adding in the least to the strength of the beer; no injury however is done to the beer by this means, and in commerce the practice is in a great measure necessary for the purpose of a quick sale. But for domestic purposes this is scarcely of any consequence; for, if the fermentation has been carried on properly, the beer will be in a few weeks as clear as is in general required, even though the proportion of the malt employed in brewing it should not have been more than two bushels to the barrel: the same degree of transparency may indeed be acquired in a few days by producing fermentation at a high temperature. The full range of temperature as applicable to the process of fermentation is not any where accurately defined: it is generally however understood that it proceeds in a languid manner at a temperature lower than 50; and that the rapidity of it increases with increased temperature. In one instance, it commenced

very favourably at a temp. as high as 108; and the liquor being then exposed to a temp. of about 60, fermentation went on in the usual manner, and the beer was very transparent in two days. The rapidity of fermentation depends also in part upon the quantity of yeast employed *.

The extrication of air during the process of fermentation and the consequent diminution in sp. gr. and increased transparency of the liquor are obvious under common circumstances: in order to ascertain more accurately the nature of these phenomena the following method was employed.

A quart bottle of perfectly transparent and colourless flint-glass was completely filled with some wort, to which yeast had

* Wort, unless it contains a very small proportion of saccharine matter, will ferment without the addition of any yeast. In one instance two quarts of yeast were added to $3\frac{1}{2}$ gallons of wort, in a small barrel, at the temp. of 80: fermentation commenced within two minutes after the addition of the yeast; and for half an hour a froth continued to rise from the mouth of the barrel as rapidly as when a bottle of fermented liquor that has been kept long corked is suddenly opened.

been just added; it was then immediately stopped with a cork, through which a small bent glass tube had been previously passed; the cork being then cemented accurately with melted wax the only communication between the outer air and the inside of the bottle was by means of the tube; the end of which being immersed under water none of the external air could find admission, while any air that should be extricated from the liquor, as it must ultimately pass out at that end of the tube which was immersed under water, could easily be received in a vessel inverted over the aperture of the tube.

This description of the common pneumatic apparatus is inserted for the convenience of those who have not been in the habit of making chemical experiments; and will therefore be excused by those to whom the apparatus itself is familiar.

It would be tedious and beyond the purpose of this treatise to detail all the minute circumstances of the experiments to which

the foregoing apparatus was applied: it is sufficient for the present to say that in that apparatus the process of fermentation was repeated several times; and the phenomena of the several experiments corresponded sufficiently closely with each other to justify the following general description *.

In a few minutes a sediment is deposited consisting of the yeast and of the heavier opaque particles of the wort: immediately after which a number of minute bubbles of air are disengaged from every part of the surface of the sediment; and many of these carry up with themselves detached particles of the yeast: some of these particles sink again by their own weight; others adhering to the edge of the glass remain fixed, and successive particles are gradually attached to them till at length the whole surface of the liquor is covered †.

* In most of the experiments the fermentation was produced at a high temperature, and the phenomena therefore succeeded each other more quickly than they would otherwise have done.

† This forms what is called the "head" of the beer; which by many is mixed again with the fermenting liquor

In proportion as these bubbles are disengaged the colour of the sediment becomes lighter, the change commencing at the surface and penetrating further as the process advances; from which circumstance it appears evident that the production of the air is connected with this change in colour: and from the loss of weight in the fermenting mass it is probable that this change of colour is attended with a loss of substance: the air extricated during fermentation is that which is called Fixed Air, and which is known to possess acid properties.

Those who are prepared to think scientifically on the subject will perhaps be dis-

two or three times during the fermentation; and as this head consists of those very particles from which fermentation proceeds, the reason of this practice is apparent. It seems however extraordinary, considering the close connexion between the proportion of saccharine matter held in solution in the wort and of spirit of wine produced by fermentation, that these bubbles should not be seen originating from every part of the fermenting mass. The probability is that they are extricated from every part, but that from circumstances with which we are at present unacquainted they cannot be readily seen.

posed to allow that the substance apparently separated from the sediment of the fermenting mass becomes one of the constituent parts of the air which is at the same time extricated; and that the other constituent part of that air, on which its acid character depends, has been afforded by the decomposition of the water. If this supposition be true, the connexion between the diminution of the saccharine matter and the presence of the spirit of wine is easily explained.

In three instances it was found that the weight of air produced very nearly corresponded with the loss of weight in the liquor; and that at least $\frac{9}{10}$ of the volume of the air produced was of that kind called Fixed Air.

These are the principal remarks which have occurred on the nature of fermentation in the course of the foregoing experiments; and the author hopes to find opportunities of pursuing them further; in which case the results, should they be thought of sufficient

consequence, will be published: but he rather hopes that others who have more leisure than himself will direct their attention towards the investigation of this subject, and throw some light on a branch of Chemistry as yet but very imperfectly understood.

THE END.

ERRATA.

Pag. 18. l. 3. from the bottom, for 2600 to 2600,5 read 2600.5 to 2600.

Pag. 19. l. 16. for 35.5 read 35.25.

Printed by Nathaniel Bliss, Oxford.

$[A]^2 B C^4 D^2 E - 1^4 K^2 = 34$

c.+ $\frac{p}{2}$ m.l.

R 114