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The Germination Of Barley, With Restricted Moisture

T. Cuthbert Day

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STATE OF FUNDS.

Amount of Funds at close of Session 1893-94	.	.	£64	13	3
Deduct—Decrease during Session 1894-95, as above	.	.	2	14	10
<hr/>					
Amount of Funds at close of Session 1894-95	.	.	£61	18	5
Being:—Sum on Current Account with Union					
Bank	.	.	£5	7	7
Sum in Deposit Receipt	do.		60	0	0
<hr/>					
			£65	7	7
Less due to Treasurer	.	.	3	9	2
<hr/>					
			£61	18	5
<hr/>					

On the motion of Dr. WILLIAM CRAIG, seconded by Professor BAYLEY BALFOUR, the report was adopted and the Treasurer thanked for his services.

Miss MADDEN exhibited dried plants from Queensland.

Mr. R. STEWART M'DOUGALL exhibited a piece of wood from a table riddled by *Anobium domesticum*, and described a number of allied species.

Mr. JAMES GRIEVE exhibited a piece of stem of Holly, which he had budded forty years previously, showing scars from the budding.

From the Royal Botanic Garden were exhibited plants in flower of—*Cattleya labiata Percivaliana*, *Cypripedium venustum*, *C. Leeatum*, *C. Dautherii*, *Pleurothallis ornata*, *Masdevallia polysticta*, *Oncidium Cavendishianum*, *Epidendrum paniculatum*.

The following papers were read:—

THE GERMINATION OF BARLEY, WITH RESTRICTED MOISTURE.
By T. CUTHBERT DAY.

I propose to deal in this paper with a subject which is of some interest to brewers and distillers, namely, the influence of moisture during the germinative period of barley. That moisture, irrespective of changes in tempera-

ture, has a stimulating action during germination, as well as at other periods of growth, is a well-known fact. The problem for brewers and others using malted grain to solve, is the amount of moisture required to produce the necessary changes at the usual temperature of growth, in order that the resulting malt may have those properties most suited to their wants. The determination of this degree of moisture is of considerable importance, since an inadequate supply prevents a sufficient metabolism of the constituents of the endosperm; while with a too abundant quantity the internal changes are carried too far, and besides the waste of starch and other desirable substances, there are apt to be formed certain nitrogenous compounds of a soluble nature, which, though of service when in moderate quantity, become a source of trouble if they are unduly predominant. Practice has of course determined for different brewers the amount of moisture to be employed by them in producing a malt most suited to their requirements, still many of them work rather in the dark in this respect, and I thought an inquiry into the subject might be of some service in bringing to light a few points in connection with the influence of moisture on germinating barley.

With this object in view I have carried out a series of experiments on different barleys, with varying degrees of moisture, to determine the following points:—

1. The Quantity of Carbonic Anhydride exhaled.
2. The Dry Weight of the Embryo at the end of the Germinative Period.
3. The Ratio of the Weight of Carbonic Anhydride exhaled to the Increase in the Dry Weight of the Embryo.
4. The Amount of Moisture in the Endosperm and in the Embryo at the end of the Germinative Period.
5. The Activity of Growth as shown by the Daily Amount of Carbonic Anhydride exhaled. This point being made plain by the construction of curves.

I do not propose, in this paper, to touch the problem connected with the compounds produced by metabolism under varying conditions of moisture. I have done some

work on this point, and shall reserve the results for a possible future communication, as a consideration of them now would take up a good deal too much time. I will merely state in this connection that the effect of increased moisture appears to increase in a considerable degree the amount of metabolism which takes place without altering to any great extent its character as is the case under the influence of increased temperature.

METHOD OF EXPERIMENT.

Experiments were performed with three kinds of barley, viz.:—Hungarian, Scotch Chevalier, both of them two-rowed barleys, and ordinary Smyrna, a six-rowed variety.

The degree of moisture for germination was determined by steeping in distilled water, at a temperature of 57° F., for 24, 48, 72, or 96 hours. In each experiment 100 corns were carefully selected to ensure uniformity as much as possible. These were weighed and then steeped for the desired period, changing the water several times. At the close of the time for steeping the water was drained off, the corns well washed three times with fresh water, and adhering moisture removed by gentle pressure in a clean cloth. The corns were then weighed again. The steep water and washings were collected and evaporated to dryness, and the weight of the substances removed from the barley was carefully determined. This weight added to the increase in weight of the corns during steep, gave the total quantity of moisture absorbed. In order to ascertain the absolute quantity of moisture present in the corns, a separate sample of the original barley was ground and dried in vacuo at 100° C., and the natural moisture determined in this way. The amount of natural or original moisture added to the quantity absorbed during steep gave the absolute quantity of moisture present in the corns to be experimented upon. The steeped corns, after being weighed as above, were introduced into a small flask like that in the figure. This flask was immersed in water up to the mark F in the figure, contained in a large vessel holding about 9 gallons, the temperature being always kept constant by means of a small gas flame regulated by a thermostat.

In Fig. 1, A represents the small flask of about 100 c.c. capacity. B is the entrance tube for the air supply, it is connected with an apparatus for removing carbonic anhydride from the air. C is a small U tube containing little glass beads and a few drops of water. The air in passing through this becomes exactly saturated with water vapour at 57° F., and in this state it cannot take any moisture from the germinating corn, neither can the corn extract any moisture from the air supplied to it. Under these conditions the quantity of moisture given to the barley during steeping is kept constant throughout the experiment. D is the exit tube for the air. It is furnished at E with a small side tube or trap which is intended to

Fig. 1.

intercept any condensed moisture from the upper cold part of the tube and prevent it getting into the flask. The upper extremity of the tube F is connected with a tube and bulbs containing strong sulphuric acid for drying the air as it comes from the flask, and the dried air is then passed through potash bulbs, etc., which remove the carbonic anhydride coming from the barley. The carbonic anhydride absorption apparatus was weighed once a day to ascertain the quantity of the gas absorbed. Air was drawn through the apparatus very slowly and continuously from start to finish of an experiment, except just at the times when the weighings were performed, by a carefully designed aspirator in which the speed of the air current could be easily regulated. All parts of the apparatus were made as small as possible on account of the small quantity of barley operated upon, and the slowness of the aspiration. In order to save time four pieces of apparatus, identical in detail, were fitted up, the four flasks being all immersed in the same large vessel, which enabled me to conduct four experiments at the same time.

The germination of the barley was carried on in this apparatus, usually from 12 to 16 days. At the end of

that time the barley was extracted from the flask and weighed. In every case it was found that the germinating corn had lost weight, and that the loss very nearly corresponded to the weight of carbon oxidised to carbonic anhydride and removed by the current of air passing through the apparatus. To be exact, the loss of weight suffered by the corn is always a little less than that accounted for by the carbon removed, this is due to the fact that a small amount of oxygen is absorbed and retained by the germinating barley, and is not again excreted in the form of carbonic anhydride. This small loss in weight of the germinated grain is a good indication that the experiment has been successfully carried out, and that the grain has neither gained nor lost in moisture since the start of the experiment. As a matter of fact, there is always a small increase in the amount of moisture in the grain, which is due to the process of respiration. If we take COH_2 to represent the formula of a carbo-hydrate, it is evident that if sufficient oxygen be supplied to convert the contained carbon into carbonic anhydride, we have OH_2 , *i.e.* water, left. This water remains in contact with the seed.

Having weighed the 100 corns after germination as above, the next thing was to find the amount of moisture present in the embryos, and in the endosperms. In order to do this 20 corns were selected and weighed at once. The weighed corns were put into a watch glass and placed under a large bell glass containing a sponge saturated with water to keep the air moist. The corns were then dissected as quickly as possible with a small scalpel, and the embryos were placed in a weighed porcelain boat, the endosperms, with the husk, being placed in a similar weighed boat. Both the boats, except when necessary, were kept under the bell glass, so as to minimise the loss of moisture during the operation as much as possible. As soon as the dissection was complete the boats were weighed. A loss of moisture was always found to have taken place during dissection in spite of all precautions. This loss was always divided, and half given to the moisture subsequently found in the embryos and half to that found in the endosperms. To determine the quantity of moisture the boats were placed in a wide glass tube surrounded with boiling water,

m.m.g., CO₂

HUNGARIAN BARLEY GERMINATING.

Curves showing Carbonic Anhydride produced,
m.m.g., 100 corns, 57-58° F.

Curve 1.	Barley steeped 24 hours.	Total Moisture.
2.	48 "	34.86 per cent.
3.	72 "	40.54 "
4.	96 "	42.93 "
		45.39 "

FIG. 1.

$m.g., CO_2$

FIG. 2.

510	SCOTCH CHEVALIER BARLEY GERMINATING.			
500	Curves showing Carbonic Anhydride produced,			
490	$m.m.g., 100\text{ corns}, 67.68^\circ F.$			
480	Total Moisture.	Curve 1.	Barley steeped 24 hours.	
470	35-90 per cent.	2.	"	48
460	40-38	"	"	72
450	42-50	"	"	96
	44-78	4.	"	"

FIG. 3.

HUNGARIAN BARLEY GERMINATING.

Curves showing Carbonic Anhydride produced,
m.m.g., 100 corns, 57-58° F.

Curve	Barley steeped	Total Moisture.
1.	72 hours.	43.07 per cent.
2.	96 "	45.31 "

m.m.g.,
 CO_2

CHEVALIER BARLEY GERMINATING.

Curves showing Carbonic Anhydride produced,
m.m.g., 100 corns, 57-58° F.

Curve	Barley steeped	Total Moisture.
1.	72 hours.	42.95 per cent.
2.	96 "	44.85 "

FIG. 4.

FIG. 5.

FIG. 6.

FIG. 8.

through which *very dry* air at a pressure of about 10 to 20 M.M. of mercury was slowly aspirated. After 12 hours the boats were taken out and again weighed, the loss giving the amount of moisture in each case.

Having now described as fully as necessary the method of experiment followed, I will proceed to discuss shortly a few of the results obtained under the five heads before mentioned.

1. The Quantity of Carbonic Anhydride exhaled.—These experiments show clearly the influence of moisture on the amount of this gas produced; an increase of moisture always producing a corresponding increase in the carbonic anhydride. When the moisture is considerably increased it is invariably found that during the first day or two of germination the quantity of carbonic anhydride excreted is a little less than for lower degrees of moisture, but the grain soon recovers its partial drowning as it were, and increased activity due to increase of moisture soon asserts itself. The effect of moisture on the production of carbonic anhydride is clearly shown in Table I., and graphically in the curves on diagrams Figs. 1 to 4. I need give but one instance here:—Scotch Chevalier barley steeped for 24 hours was found to contain 35·90 per cent. water. On germinating for 14 days at constant temperature the carbonic anhydride collected weighed ·2330 gramme. The same barley steeped for 96 hours contained 44·78 per cent. water, and produced in 14 days, at the same temperature, ·4852 gramme carbonic anhydride. So for an increase of moisture amounting to 8·88 per cent. the quantity of carbonic anhydride was more than doubled.

2. The Dry Weight of the Embryo at the end of the Germinative Period.—Table II. gives the results obtained on this point. Corn germinated for 14 days, after a 96 hours' steep, gives a dry embryo weighing rather more than double that obtained when the steep is only 24 hours.

3. The Ratio of the Weight of Carbonic Anhydride exhaled to the Increase in the Dry Weight of the Embryo.—When the number representing the increase in the dry weight of the embryo during germination is divided by the weight of carbonic anhydride exhaled, it is found that the product increases in value as the quantity of moisture

used in germination is increased. So it appears that with the larger quantities of moisture, the embryo increases more in weight for the same amount of carbonic anhydride exhaled than it does when less moisture is present. This feature is well brought out in Table I.

4. The Amount of Moisture in the Endosperm and in the Embryo at the end of the Germinative Period.—Roughly speaking, the percentage of moisture found in the embryo at the end of the germinative period, was always nearly double of that found in the endosperms, the disparity being always greatest the smaller the quantity of moisture employed in the experiment. Thus, for Scotch Chevalier barley, steeped 24 hours with 35.90 per cent. moisture, gave, after germination, endosperms with 32.64 per cent. moisture, and embryos with 63.60 per cent. moisture; the ratio between the two being 1.95. The same barley, steeped for 96 hours with 44.78 per cent. moisture, gave, after germination, endosperms with 38.56 per cent. moisture, and embryos with 68.46 per cent. moisture; the

Fig. 2.

ratio between the two being 1.78. Table III. gives a complete review of all the results obtained under this head. Three experiments to ascertain the initial amount of moisture in the embryos, immediately after steeping for 72 hours, and before germination had commenced, showed about 60 per cent., a quantity considerably below any recorded in Table III. The results of the moisture determinations seem to show that the new forming tissue cannot grow with any degree of success unless the moisture it contains is above 63 per cent. All the barley which had only a 24 hours' steep, grew to a very slight extent. The above accompanying rough figure (Fig. 2) will convey an idea of the amount of growth for different lengths of steep after 14 or 15 days' germination at 57° F.

5. The Activity of Growth as shown by the Daily Amount of Carbonic Anhydride exhaled.—Taking the production of carbonic anhydride as the measure of growth during germination, the period of greatest activity, with varying quantities of moisture, was generally found to occur about the third or fourth day, the period being generally somewhat delayed with increase of moisture, especially in the case of the Scotch and Smyrna barleys. After this point of greatest activity is reached, there is a gradual fall in vitality to the end of the 14 days or so according to the experiment.

The progress of vital activity is well shown in the series of curves on diagrams Figs. 6, 7, and 8.

Four experiments, two with Hungarian barley, and two with Scotch Chevalier, were performed to ascertain if, at the period of greatest vitality, as indicated by the curve of daily excretion of carbonic anhydride, the moisture present in the embryo was also at its greatest amount. The result showed that if the germination were stopped about the fourth or fifth day, the moisture present in the embryo was then at its greatest quantity, ranging from 70.94 per cent. to 74.57 per cent., and considerably higher than that found in any experiment lasting 14 days or so. The curves relating to these four curtailed experiments will be found on diagrams Figs. 4 and 5, and the numerical results in all the tables at the end.

This, then, is all I have to bring before you to-night. I have only just mentioned as it were the results obtained, as it would not be of interest to wade through a lot of tables. The results of the work, if meagre, will have served their end if they suggest to others, who have more time at their disposal than I have, some line of inquiry that will lead to an increase of our knowledge on many of the obscure points connected with germination.

TABLE I.—Total Carbonic Anhydride excreted, and total increase in the dry weight of the Embryo, together with the ratio of the weight of Carbonic Anhydride to the *increase* in the dry weight of the Embryo, in germinating Barley under different degrees of moisture, grown at a Temperature of 57° to 58° F. 100 Corns of Barley in each case.

Kind of Barley.	Hours Steep.	Total Moisture in Barley before Germination.	Carbonic Anhydride Excreted.	Increase in Dry Weights of Embryo.	Ratio of Carbonic Anhydride to Increase in Dry Weight of Embryo.	Days Germinated.
		%	Grammes.	Grammes.	Wt. Embryo CO ₂	
Hungarian	24	34·86	·1705	·1555	0·912	12
Do.	48	40·54	·3379	·3835	1·135	16
Do.	72	42·93	·3703	·4165	1·124	15
Do.	96	45·39	·3907	·5290	1·354	14
Chevalier	24	35·90	·2330	·2005	0·860	14
Do.	48	40·39	·3678	·3225	0·877	15
Do.	72	42·50	·4037	·4110	1·018	14
Do.	96	44·78	·4852	·5890	1·214	14
Smyrna	24	32·90	·1572	·1155	0·735	14
Do.	48	37·16	·2726	·2040	0·748	14
Do.	72	40·14	·3349	·4040	1·206	15
Do.	96	42·95	·3991	·5920	1·483	15
Hungarian	72	43·07	·1010	·1290	1·277	4
Do.	96	45·31	·1532	·2640	1·723	5
Chevalier	72	42·95	·1694	·2860	1·688	5
Do.	96	44·85	·1793	·3170	1·768	5

TABLE II.—Weight of the Embryo in the natural moist state, and in the dry state, of Barleys germinated under different conditions of moisture, grown at a Temperature of 57° to 58° F. 100 Corns of Barley in each case.

Kind of Barley.	Hours Steep.	Weight of 100 Embryos, Moist.	Weight of 100 Embryos, Dry.	Dry Weight of Embryo compared with Natural Weight of the Barley.	Days Germinated.
		Grammes.	Grammes.	%	
Hungarian	24	·850	·316	7·30	12
Do.	48	1·618	·544	12·57	16
Do.	72	1·747	·577	13·33	15
Do.	96	2·184	·690	15·95	14
Chevalier	24	·996	·362	7·16	14
Do.	48	1·513	·484	9·57	15
Do.	72	1·825	·573	11·34	14
Do.	+ 96	2·381	·751	14·85	14
Smyrna	24	·668	·253	4·63	14
Do.	48	1·288	·341	6·25	14
Do.	72	1·664	·541	9·91	15
Do.	96	2·260	·729	13·35	15
Hungarian	72	1·140	·290	6·70	4
Do.	96	1·220	·425	9·82	5
Chevalier	72	1·541	·448	8·59	5
Do.	96	1·782	·479	9·47	5
Hungarian	...	Ungerm- inated	·161	3·72	...
Chevalier	...		·162	3·20	...
Smyrna	...		·137	2·51	...

TABLE III.—Moisture in the Endosperm and in the Embryo of Barleys germinated under different conditions of moisture, and grown at a Temperature of 57° to 58° F., and the ratio of the moisture in the Endosperm to that in the Embryo. 100 Corns taken in each case.

Kind of Barley.	Hours Steep.	Moisture in Steeped Barley. Absolute.*	Moisture in Endosperm after Germination.	Moisture in Embryos after Germination.	Ratio of Moisture. Embryo Endosperm.	Days Germinated.
		%	%	%		
Hungarian .	24	34·86	31·61	62·79	1·99	12
Do. .	48	40·54	35·94	66·35	1·85	16
Do. .	72	42·93	36·84	66·95	1·82	15
Do. .	96	45·39	38·50	68·41	1·78	14
Chevalier .	24	35·90	32·64	63·60	1·95	14
Do. .	48	40·39	35·98	67·98	1·89	15
Do. .	72	42·50	37·49	68·60	1·83	14
Do. .	96	44·78	38·56	68·46	1·78	14
Smyrna .	24	32·90	29·64	62·15	2·10	14
Do. .	48	37·16	33·39	65·74	1·97	14
Do. .	72	40·14	35·39	67·46	1·91	15
Do. .	96	42·95	37·45	67·73	1·81	15
Hungarian .	72	43·07	37·08	74·57	2·01	4
Do. .	96	45·31	38·43	74·17	1·93	5
Chevalier .	72	42·95	37·57	70·94	1·89	5
Do. .	96	44·85	38·84	73·13	1·88	5

* The absolute moisture means the water absorbed during steep, plus the natural moisture of the barley.

NOTE.—Average Natural Weights of 100 Corns :—
Grammes.

Hungarian Barley .	4·327	Natural Moisture .	%
Kiln-dried Chevalier do.	5·057	Do. .	14·46
Smyrna do.	5·460	Do. .	11·13
		Do. .	11·90

THE TWISTING OF THE LEAVES ON THE HORIZONTAL SHOOTs OF THE FLAT-LEAVED SPRUCES AS CONTRASTED WITH THE SAME PHENOMENON IN OTHER FIRs. By A. D. RICHARDSON.