The Effect of a Wet and Dry Steep-Out on Barley Respiration and Malt Modification Time[1]

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ABSTRACT

A comparison of the effect of a wet (slurry) and dry steep-out on barley respiration and malt modification time was made. Barley respiration was determined with the Warburg apparatus. Malt modification was assessed according to ASBC standard methods. The data indicate that a wet steep-out immediately reduces barley respiration by 26%, with a recovery time of up to 28 hr. The time required to reach maximum respiration during germination is also delayed by at least 24 hr. This respiration drop can be caused by either a prolonged submergence time or hydrostatic head pressure. In a production facility, hydrostatic head pressure is probably the dominant factor. Neither root injury nor temperature change during the transfer from steep to germination compartments contributes to the observed respiration "shock". A slower modification rate is associated with the respiration drop caused by the wet transfer.

Key words: *Hydrostatic pressure, Malt, Modification time, Respiration, Steep-out.*

Numerous reports can be found in the literature which deal with the influence of oxygen on barley, and with the role that barley respiration plays during the conversion of barley to malt.

The works of Kirsop and Pollock (6), and Dahlstrom, *et al.* (1) led to the so-called aerobic continuum concept. Briefly, it may be described as an adequate, uninterrupted supply of oxygen to the barley from the beginning of steep through germination. The importance of this principle during the malting process has also been recently noted by Olsen (8) and Hyde (5).

The reports of DeClerck (2), Lang (7), and Eyben and van Droogenbroeck (4) are of particular significance since they clearly demonstrate the importance of using barley respiration during the steep and germination processes as a tool for assessing modification rates. Furthermore, Eyben and van Droogenbroeck (3) present evidence, from a micro-malthouse study, that hydraulic pressure has an inhibiting effect on barley respiration. Concurrent with the decrease in respiration, they found that pressure also resulted in malt of lower quality. They suggested that this phenomenon accounted for their observations that, in certain malthouses, hydraulic pressure from pumping barley out of steep is the cause of slow, uneven germination and malts of low quality.

Since we are interested in maximizing the efficiency of malting, while maintaining high standards of quality, we used the barley respiration technique to monitor performance of a production malting facility.

METHODS

The Warburg apparatus was used to monitor barley respiration. Calibration was performed and microliters of oxygen uptake determined according to the methods described by Umbreit, *et al.* (9). Kernels, removed from steep and germination beds at various time periods, were blotted to remove excess surface moisture, and placed in the Warburg apparatus at 17°C within 15–20 min after sampling. Each test was done in triplicate. Barley dry weight was determined gravimetrically after 24 hr at 90°C.

The number of seeds placed in the Warburg was determined by their volume displacement of water (3.0 ml). Since the relationship between a fixed number of seeds employed and final dry weight differed little, a standard dry weight was adopted for all Warburg calculations.

Initial data demonstrated that respiration was linear for all samples, over a 45-min Warburg testing period. Hence, that Warburg respiration period was used throughout. Results were then converted to QO_2 or microliters of oxygen uptake/mg dry weight/hr.

In order to mimic a dry steep-out procedure in the production facility, barley was removed just prior to steep-out and placed in a perforated wire basket which was located in the correct germination bed. Wet steeped-out barley, the normal production method, was treated in the same manner immediately after arrival in the germination bed. Kernels were removed and analyzed at appropriate time periods.

Studies were also performed in an 800-lb capacity pilot malthouse. Since the steep, germination, and kiln processes are in the same vessel, a wet steep-out was mimicked by a prolonged submergence time of 40 min. With this exception, the production malting procedure was followed in the pilot facility. Barley moisture at steep-out ranged from 41.5 to 42.5%.

When the role of rootlet respiration was assessed, the de-rooted sample was obtained by clipping the rootlets before placement in the Warburg apparatus.

To determine hydraulic pressure effects, a laboratory device was constructed that would apply known amounts of air pressure to barley submerged in a large glass container. After decanting the water, the samples were incubated in a damp chamber at room temperature for 48 hr while root growth and respiration were monitored.

Barley was steeped by a combination spray and immersion method, with sprays applying water to the barley throughout the steeping procedure. During this time air was drawn through the bed by downdraft fans. Periodically, the barley was submerged and aerated with a geyser system. This steeping submergence and aeration operation was completed within 20 min. At steep-out, barley was submerged, continuously aerated via the geyser system and dropped by gravity to the germination beds below. Aeration of the germination beds began immediately after filling was complete. Throughout most of the testing period a 48-hr steep time was employed. Barley steep-out moisture ranged from 41.5 to 42.5%. Final malt quality was assessed according to standard ASBC procedures. Moravian two-row barley was used throughout this study.

RESULTS

Respiration data gathered from various maltings of Moravian barley are shown in Fig. 1. Several interesting points are evident. First, the rate of respiration increase was essentially linear throughout the steeping process. Second, an immediate drop in barley respiration occurred after the steep-out procedure. This drop averaged 26%. Third, approximately 20–28 hr of germination time was required before respiration recovered to its original pre-steep-out rate. The dashes used to denote this time in Fig. 1 is not the actual recovery profile. Fourth, the two to three 15–20 min immersions, with aeration from the geyser system during the steeping process, did not cause a respiration lag. Oxygen uptake

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was determined shortly before and after the immersions. Consequently, the data do not suggest that the respiration of barley is unaffected while underwater, but that if affected, the recovery time is extremely short.

After the 20–28 hr lag period, respiration proceeded in a vigorous manner for about 115 hr, then it reached its maximum and a plateau was established. Lang (7) also observed a respiration plateau, and in some cases a drop in barley respiration occurring toward the end of germination.

Interest was focused on the drop in respiration and the recovery time period. In order to determine if the same phenomenon would be observed with a dry steep-out, basket maltings in the production environment were performed as described in the **Methods** section. The data in Fig. 2 clearly demonstrate that the respiration lag at steep-out did not occur under dry steep-out conditions. Furthermore, in the absence of the respiration lag, respiration maximum was obtained approximately 30–40 hr sooner.

Both test malts (Table I) were kilned after 96 hr of germination time. Clearly, the quality of the dry steeped-out malt is superior. These data suggest that: 1) under these conditions the respiration profile is a relatively accurate method of assessing modification rates, and 2) the respiration lag associated with a wet steep-out procedure increases the time required for malt modification.

The pilot malthouse was then employed in an attempt to duplicate these initial findings. Although the 40-min submergence time (mimic wet steep-out) does cause a drop in respiration (Fig. 3), the recovery time is reduced. This test indicates that not only is the respiration lag approximately 16–18 hr, but it nearly recovers to the same level as the dry steep-out sample. Regardless, the malt analysis (Table II) indicates that dry steeped-out barley modifies faster than the wet steeped-out barley, in this case approximately 24 hr sooner.

Several avenues of investigation were initiated in an attempt to determine more precisely the factor causing the drop in respiration. The germination beds were several degrees cooler than the steep tank environment. Conceivably, that temperature difference could account for the drop and lag in barley respiration. However, if temperature change were a factor, the initial dry steep-out samples should have shown a drop in respiration; they did not.

During the course of the study it was observed that barley rootlets, before steep-out, were turgid, while just after the wet steep-out procedure they were flaccid. Therefore, it appeared that root damage during the steep-out procedure was causing the respiration drop. To evaluate this, barley was obtained before steep-out, and

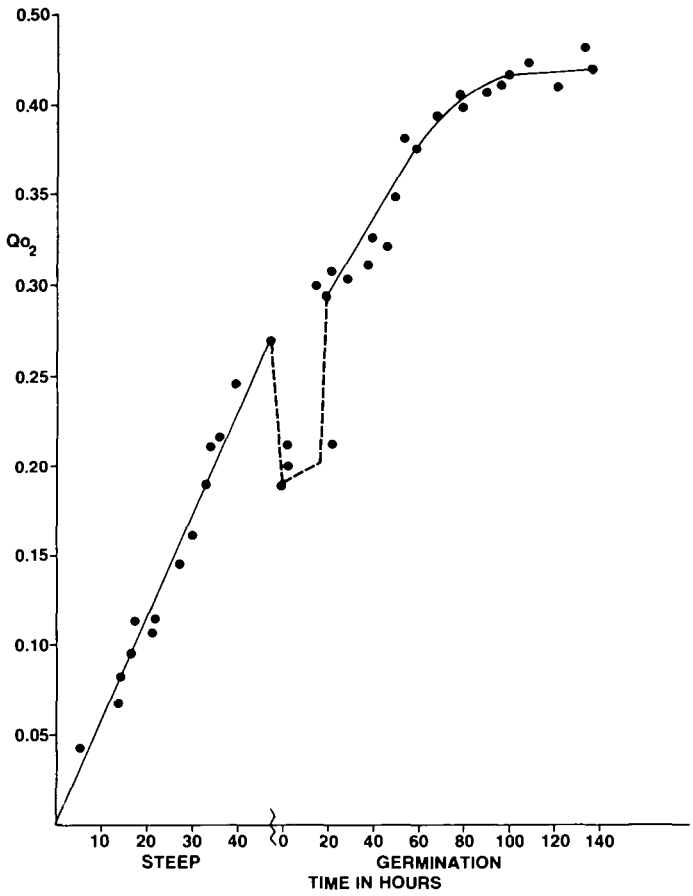

Fig. 1. The composite respiration profile for barley during steep and germination. Each dot represents the mean of three replicates.

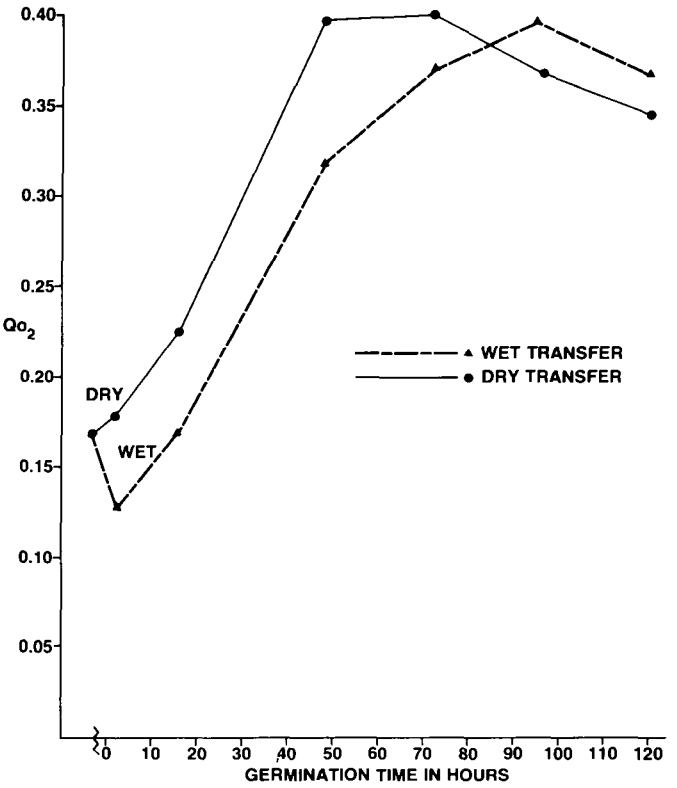

Fig. 2. Barley respiration during germination after a wet and dry steep-out procedure.

TABLE I
Malt Analysis of Barley Transferred Wet and Dry[a]

Malt Quality Factors	Steep-Out Method	
	Dry	Wet
Extract, fine grind, dry basis	79.1	79.3
Extract, coarse grind, dry basis	76.6	75.1
Fine/coarse difference	2.5	4.2
Wort color	1.47	1.42
Clarity	C	C
Conversion, minutes	5	5
Speed of filtration ml/hr.	178	158
pH	5.83	5.88
Diastatic power	112.0	101.0
Alpha amylase	44.0	36.0
Soluble protein	5.41	5.34

[a]Germination time 96 hr.

the rootlets of one set were completely removed. The other set received no treatment. Both samples displayed a parallel drop in respiration and a similar recovery profile (Fig. 4). This clearly shows that root damage, either physical or otherwise, does not account for the drop in respiration associated with the wet steep-out.

It is noteworthy that even though this test showed the smallest drop in respiration, the recovery time remained nearly 20 hr. This suggests that the percent drop in respiration is not directly related to recovery time.

After eliminating both temperature shock and root damage as factors causing the respiration lag, a more detailed study of barley respiration during the steep-out procedure was initiated. The respiration of barley was monitored during the entire procedure, both from the steep tank and as it entered the germination bed. During steep-out (approximately 30 min) barley obtained from the tanks showed a slight decrease in respiration (Fig. 5). On a comparative basis, barley samples obtained from the steep tanks displayed considerable variability. Yet, barley from the same tanks, entering the germination compartment, suffered the respirational shock regardless of the time spent in the steep tanks (Fig. 5). These data suggest that submergence time is not the dominant factor causing the drop in respiration. Attention was then focused on the effect of hydrostatic head pressure.

Figure 6 shows the dramatic drop in respiration that occurred when barley was subjected to pressures of 50 psi for various time periods. Barley respiration dropped immediately after the pressure treatment and never recovered to control levels. Essentially the same response was observed at a pressure of 15 psi applied over the same time periods. The drop in respiration and recovery time for barley submerged in water, without pressure applied, was not consistently as low as indicated in Fig. 6, yet it was always below the control.

At the end of the 24 hr incubation period, root growth of the control and treated samples displayed the same relation shown in Fig. 6. Ranked in order of root growth, the most vigorous occurred in the control, followed by the submerged without pressure applied, and lastly the submerged with pressure applied (Figs. 7 a, b, c).

DISCUSSION

The work of Eyben and van Droogenbroeck (4) demonstrates the relation found between respiration and malt modification rates.

TABLE II
Comparison of Malt Produced by a Wet and Dry Transfer Procedure in the Pilot Malthouse[a]

Malt Quality Factors	Steep-Out Method	
	Dry	Wet
Extract, fine grind, dry basis	80.14	79.79
Extract, coarse grind, dry basis	79.13	78.76
Fine/coarse difference	1.01	1.03
Color wort	1.64	1.52
Clarity	C	SH
Conversion, minutes	<5	<5
Speed of filtration ml/hr	127	122
pH	5.9	6.0
Diastatic power	136	123
Alpha amylase	50.7	47.5
Soluble protein	...	...

[a]Dry steeped-out barley with 24 hr less germination time.

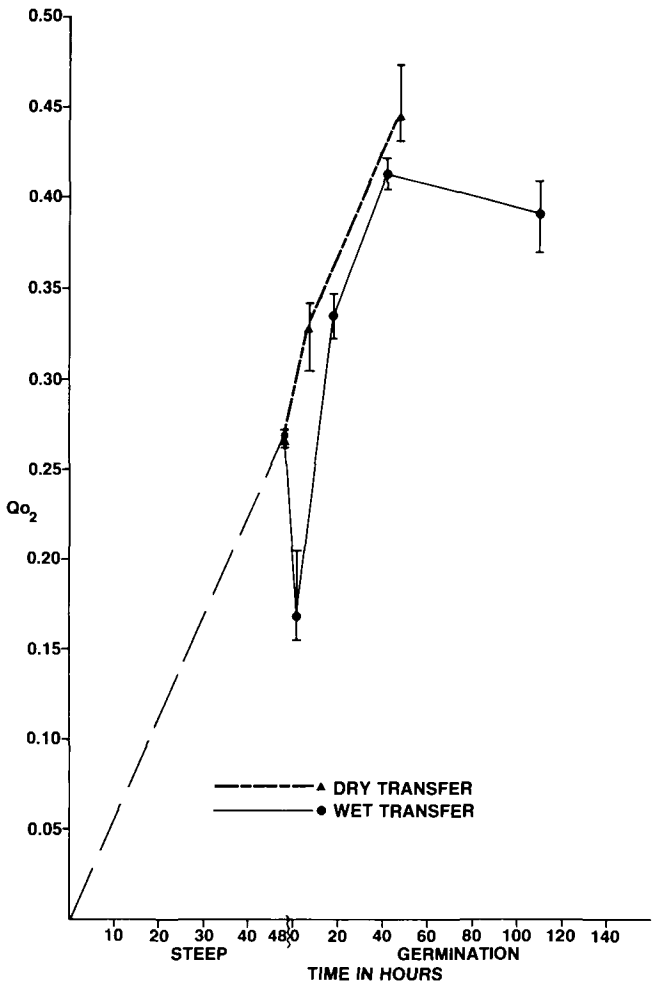

Fig. 3. Respiration profile before and after a wet and dry transfer procedure in the pilot malthouse.

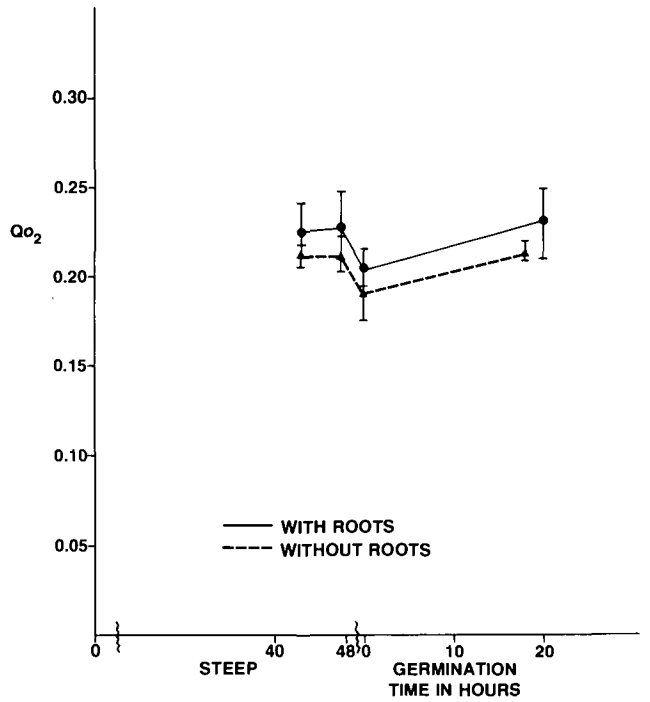

Fig. 4. Respiration of barley with and without roots before and after wet steep-out.

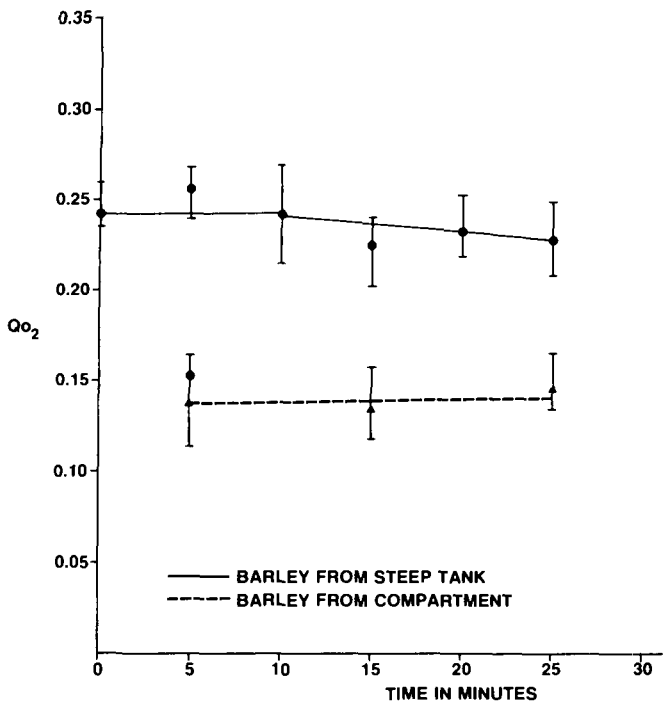

Fig. 5. Respiration of barley obtained from its steep tank and its germination compartment during the actual steep-out procedure.

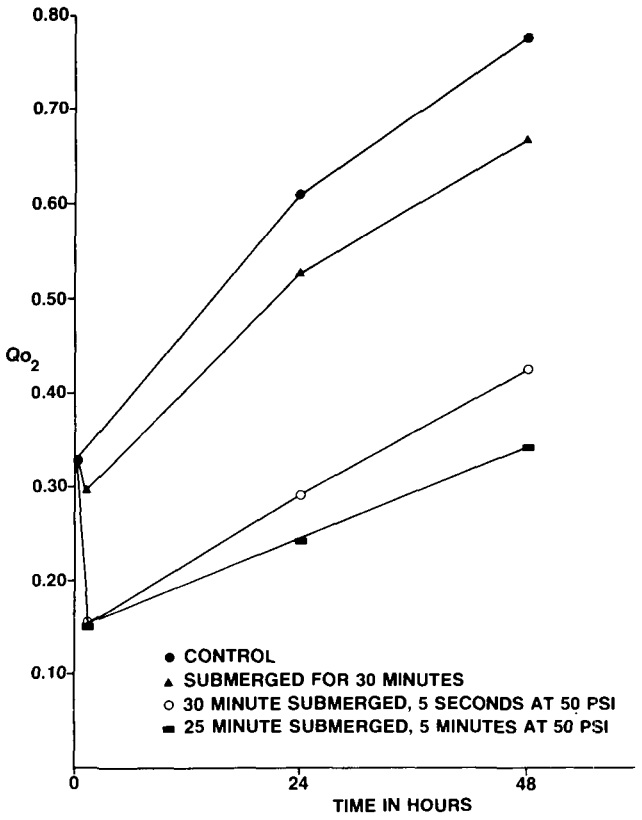

Fig. 6. Respiration of barley, obtained immediately before steep-out, subjected to submergence with and without pressure applied and then incubated in a damp chamber at room temperature.

Fig. 7a. Root growth of control sample (Fig. 6) after incubation for 24 hr.

Fig. 7b. Root growth of sample submerged for 30 min (Fig. 6) and incubated for 24 hr.

Fig. 7c. Root growth of sample submerged for 30 min and then subjected to 50 psi for 5 sec (Fig. 6). Incubation time of 24 hr.

They showed that, in general, the curve of α-amylase and diastatic power activity parallels the respiration curve during the course of germination. A significant relation exists between respiration intensity and attenuation limit. Much earlier, DeClerck (2) concluded from his study that there is a parallel between respiration rate and enzyme formation, and that the sooner the respiration maximum occurs, the better the malt. Lang's (7) work indicates that these relations do not always hold, and apparently depend to some degree on the barley variety employed. Considering this apparent anomaly, it seems probable that the relation between barley respiration and malt modification depends on the type of steeping and germination methods employed, as well as the barley variety.

This study supports the findings of DeClerck (2), Eyben and van Droogenbroeck (4), and the inferences of Dahlstrom, *et al.* (1), Hyde (5), and Olsen (8). That is, respiration rates do relate to malt modification time. The faster the respiration rate, the earlier respiration maximum occurs, then the earlier proper malt modification will be complete. In this study, a wet steep-out procedure caused a drop in barley respiration (26%), with a recovery time of 20–28 hr. Furthermore, this results in delaying the time to reach maximum barley respiration. These effects, brought about by a wet steep-out, prolong the modification of malt.

Respiration data, germination time, and malt quality parameters indicate that a dry steep-out procedure will produce malt of equal or superior quality approximately one day earlier than if a wet steep-out procedure is employed.

In their study of the effect of pressure on germination of barleys and malt quality, Eyben and van Droogenbroeck (3) found that: 1) barley's sensitivity to pressure increases during the course of germination, 2) the degree of respiratory inhibition due to pressure depends on the duration and level of the pressure, and these two parameters act in a cumulative manner, and 3) pressure causes a clear lag in the formation of amylolytic enzymes, a deficiency in extract yield, a slight deficiency in attenuation, and an elevated fine-coarse difference. Proteolytic enzymes were not greatly affected. Their data also indicate that grain depth during underwater steeping is an important consideration. For the two depths studied (5 and 10 m), both had an adverse effect on barley respiration and malt quality, though the 10 m water column was much more effective. From a practical standpoint, they emphasize the increase in germination time required with a hydrostatic pressure effect, and the possibility of using this method to reduce malting loss when gibberellins are employed at proper periods.

The present work, done primarily in a commercial malthouse, though not as intensive as that of Eyben and van Droogenbroeck (3), also indicates that hydrostatic head pressure is the primary cause of the barley respiration and modification lag. Furthermore, it seems reasonable that with the addition of gibberellins, germination time would be reduced for both a wet and a dry transferred barley. Hence, the hydrostatic pressure effect may still be the critical factor so far as malt processing time is concerned.

SUMMARY

In summary, this data, obtained to a large degree in a production environment, indicates that a wet steep-out causes an immediate drop in barley respiration. The dominant effective force is hydrostatic head pressure, although a prolonged submerged time is also effective. Associated with the respiration lag and recovery period of about one day is a requirement for a longer germination time. That is, with all other conditions equal, greater time is required with a wet steep-out. For the malting process studied, barley respiration is a relatively accurate means of assessing malt modification rates.

It should be stressed that different steeping and germination conditions might alter the relation noted in this study. Further, one might substantially eliminate the respiration lag associated with a wet steep-out if the effect of hydrostatic head pressure were counteracted.

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