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Water Absorption of Naked Barley Kernels Differing in Pearling Degrees

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Abstract

Water absorption of the major kernels (7 and 10 mesh sizes) of naked barley differing in pearling degrees at 20-50 °C was investigated. The time to reach equilibrium moisture content was reduced by half upon removal of over 20% of the outer layer of the kernel. Water absorption rate and diffusion coefficient of naked barley of 5% pearling degree at 40 °C were faster about 1.5 and 2.8 times than those of unpearled one. The activation energy of hydration for unpearled naked barley was 11.5 kcal/mole, which was decreased by approximately 0.4 kcal/mole upon increasing the pearling degree by 5%.

Key words: naked barley, hydration of naked barley

Introduction

On the water absorption by naked barley was reported by several workers[1-5]. One of the difficulties in studying hydration properties of naked barley is that the kernel sizes are not uniform. Yun *et al.*[4] demonstrated that the predominant kernel size of naked barley was 7 mesh, followed by 10 mesh kernel, of which comprised 86-94% of the total kernel, and that diffusion coefficient at 40 °C increased as the kernel size decreased.

The purpose of this study was to investigate the water absorption kinetics of major kernels (7 and 10 mesh sizes) of naked barley differing in pearling degrees.

Table 1. Average yield of pearled naked barley

Degree of pearling (%)	Yield (%)	Milling time (sec)
0	100.0	0
5	95.5	40
10	90.5	95
15	85.3	153
20	80.4	200
25	75.5	242
30	70.1	305

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Materials and Methods

Materials

One variety of naked barley (Saessal-bori) was sieved to obtain 7 and 10 mesh size kernels.

Naked barley was pearled with a Satake Grain Testing Mill (Satake Engineering Co., Japan) to remove successfully outer 5% by weight of the kernel. The pearling yield and milling time are tabulated in Table 1.

Determination of water absorption

One gram of naked barley was soaked at 20 °-50 °C water up to 48 hr. From the weight gain of the naked barley kernels the moisture content was calculated.

Analysis of water absorption rate

The water absorption rate of naked barley was analyzed by the following equation according to Becker[6]:

$$m - m_o = k\sqrt{t} \quad (1)$$

where

$$k = \frac{2}{\sqrt{\pi}}(m_s - m_o)(S/V)\sqrt{D} \quad (2)$$

In this experiment m_s was determined from the moisture gain of naked barley kernels by soaking at 40 °C for 15 min[4,6]. The volume and surface

Table 2. Dimension of naked barley

Pearling yield(%)	Length (mm)	Width (mm)	L/W	Volume (mm^3)	Surface area(mm^2)	V/S (mm)
70	4.67	3.15	1.48	2.42	4.16	0.58
75	4.85	3.19	1.52	2.58	4.35	0.59
80	5.05	3.29	1.54	2.86	4.66	0.61
85	5.25	3.24	1.62	2.96	4.82	0.61
90	5.44	3.30	1.65	3.19	5.06	0.63
95	5.64	3.42	1.65	3.46	5.35	0.65
100	5.88	3.44	1.76	3.61	5.57	0.65

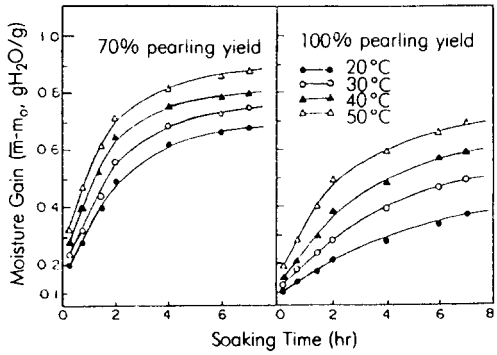

Fig. 1. Water absorption during hydration of naked barley at various temperatures.

area of naked barley kernel were calculated, on the assumption of a prolate spheroid, as described carlier[4].

A relationship between diffusion coefficient and soaking temperature were analyzed by the equation[6]:

$$D=D_o\exp(E_a/RT) \quad (3)$$

Results and Discussion

Dimension of naked barley is given in Table 2. As pearling yield was decreased all parameters were consistently decreased. Length of the kernel was more reduced than width upon pearling.

Percent reduction of volume and surface area of naked barley kernel by 30% pearling were 32.9% and 25.3%, respectively.

Water absorption

The moisture gain of naked barley as a function of soaking time at various hydration temperatures is shown in Fig. 1. The degree of moisture gain was gradually increased with decreasing the pearling yield.

Table 3. Inital moisture content (m_o) and equilibrium moisture content of naked barley and time to reach EMC after soaking in water at 40°C

Pearling yield (%)	m_o	EMC (g H_2O/g, wb)	Time to reach EMC (hr)
70	0.1173	0.8925	24
75	0.1182	0.8955	24
80	0.1183	0.8965	24
85	0.1183	0.9024	30
90	0.1183	0.9059	30
95	0.1184	0.9061	30
100	0.1275	0.9064	48

The equilibrium moisture content (EMC) of naked barley is presented in Table 3. EMC at 40°C was consistently decreased upon pealring. The time to reach EMC was reduced by about 37% upon removal of 5-15% of the outer layer of the kernel. However, the time to reach EMC for the naked barleys of 70-80% pearling degrees was only half to that for unpearled naked barley.

It was reported[4] that EMC of unpearled naked barleys for 7 and 10 mesh kernels at 40°C were in the range of 0.79-0.84 gH_2O/g and 0.87-0.92 g H_2O/g, respectively.

The relation between the moisture gain and the square root of the absorption time for naked barley at various temperatures in shown in Fig. 2. The linear relationships in Fig. 2 were maintained to 120 min for unpearled barley and 90 and 60 min at below 30°C and above 40°C, respectively, for pearled naked barleys.

The moisture gain at time zero is an indicator of the moisture content which is needed for the saturation of outer layer of the barley kernel[6].

Effective surface moisture content

The moisture gain of naked barley held a linear relation with the initial moisture content, as shown in Fig. 3. The effective moisture content was estimated by extrapolation of the straight

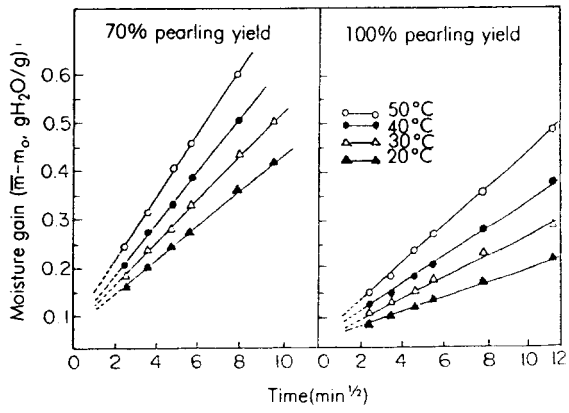

Fig. 2. Relation between the moisture gain and the square root of the absorption time for naked barley at various temperatures.

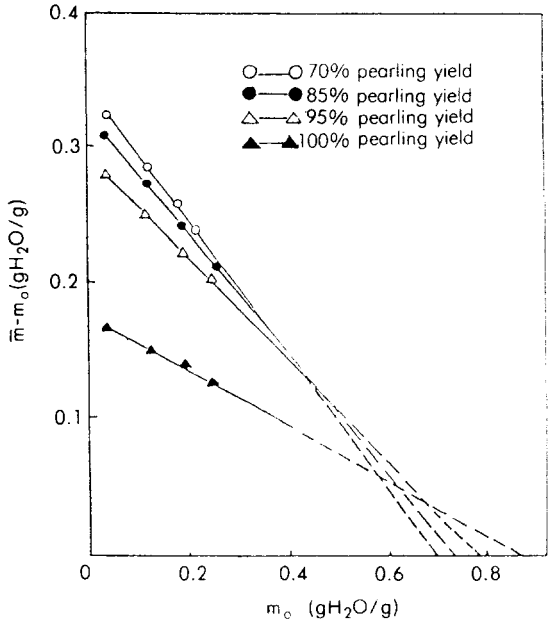

Fig. 3. Effective surface moisture content as a function of initial moisture content during hydration of naked barley for 15 min at 40°C.

line[6].

The effective surface moisture content of unpearled naked barley was 0.8701 gH_2O/g (Table 4). Mok *et al.*[3] reported that the effective surface moisture content of naked barley (Sedohadaka) of 100% pearling yield was 0.8890 gH_2O/g. The effective surface moisture content was consistently decreased as pearling yield decreased.

Table 4. Effective surface moisture content (m_s) of naked barley

Pearling yield (%)	m_s (gH_2O/g)
70	0.7011
75	0.7088
80	0.7211
85	0.7309
90	0.7573
95	0.7904
100	0.8701

Water absorption rate

The water absorption rate (k), calculated from the slope in Fig. 2, and diffusion coefficient (D) of naked barley at various soaking temperatures are presented in Table 5. Both parameters increased as the pearling degree and temperature were increased. Mok *et al.*[4] reported that the diffusion coefficients of unpearled Sedohadaka were 0.1163×10^{-5} cm^2/min at 20°C and 0.3774×10^{-5} cm^2/min at 40°C. The discrepancy in the water absorption rate between pearled and unpearled naked barleys was reported to be the difference in structure and consisting substances in kernels[4].

The water absorption rate for naked barley of 95% pearling yield at 40°C was higher by 0.0141 cm/min than that for unpearled naked barley (Table 5), which indicates that the water absorption rate was faster about 1.5 times by removal of 5% outer layer of the kernel. Diffusion coefficient was also increased 2.8 times by removal 5% of the outer layer of the kernel (Table 5).

Relationship between diffusion coefficient and a reciprocal absolute temperature is shown in Fig. 4. The activation energy calculated is presented in Table 6. The activation energy of unpearled naked barley was 11.5 kcal/mole which was in good agreement with that reported by Mok *et al.*[4]

The activation energy of naked barley was decreased by approximately 0.4 kcal/mole upon increasing the pearling degree by 5% (Table 6). However, the naked barleys of 70-80% pearling yields had essentially the same activation ener-

Table 5. Calculated values of the soaking rate parameters of naked barley

Pearling yield (%)	Soaking Temperature (C)	k (cm/min)	$D \times 10^5$ (cm^2/min)
70	20	0.0352	0.9697
	30	0.0421	1.3853
	40	0.0499	1.9492
	50	0.0588	2.7113
75	20	0.0339	0.9116
	30	0.0406	1.3084
	40	0.0489	1.8969
	50	0.0573	2.6101
80	20	0.0323	0.8523
	30	0.0378	1.1669
	40	0.0449	1.6445
	50	0.0546	2.4275
85	20	0.0306	0.7389
	30	0.0378	1.1251
	40	0.0450	1.5981
	50	0.0543	2.3266
90	20	0.0293	0.6591
	30	0.0358	0.9833
	40	0.0437	1.4668
	50	0.0535	2.1948
95	20	0.0268	0.5244
	30	0.0333	0.8050
	40	0.0409	1.2234
	50	0.0502	1.8371
100	20	0.0149	0.1331
	30	0.0194	0.2267
	40	0.0268	0.4299
	50	0.0353	0.7458

Table 6. Temperature dependence of diffusion coefficient of naked barley

Pearling yield (%)	$D = D_o \exp(-E_a/RT)$
70	$D = 1.1377\exp(-6818/RT)$
75	$D = 1.1398\exp(-6830/RT)$
80	$D = 1.1548\exp(-6916/RT)$
85	$D = 2.9829\exp(-7535/RT)$
90	$D = 5.4695\exp(-7965/RT)$
95	$D = 7.9780\exp(-8304/RT)$
100	$D = 498.2438\exp(-11545/RT)$

gies. The results in Table 6 indicates that the hydration reaction of celluloisic material of outer layer is more temperature-dependent than the

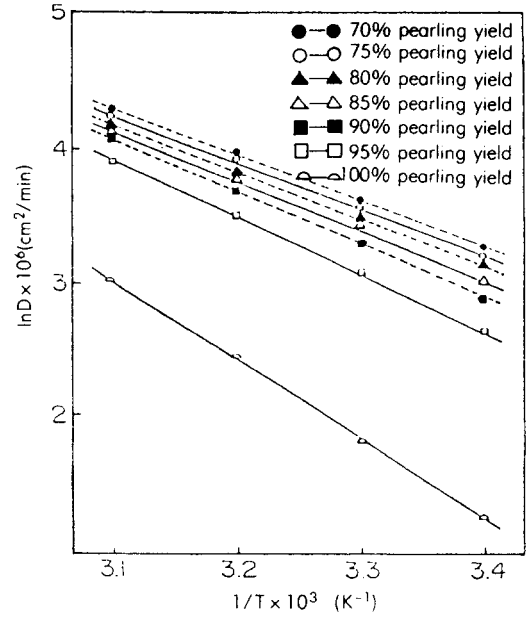

Fig. 4. Diffusivity as a function of reciprocal of temperature for naked barley.

starchy material of inner part of the kernel.

The temperature dependence of diffusion coefficient was calculated from Eq. (3) and is presented in Table 6.

Nomenclature

a : Long radius of naked barley kernel (mm)
b : Short radius of naked barley kernel (mm)
D : Diffusion coefficient (cm^2/min)
D_o : Diffusion constant (cm^2/min)
E_a : Activation energy (cal/mole)
m_o : Initial moisture content (gH_2O/g, db)
m : Moisture content at a given absorption time (gH_2O/g, db)
m_s : Effective surface moisture content (gH_2O/g, db)
R : Gas constant (1.987 cal/mole K)
T : Absolute temperature (K)
t : Soaking time (min)

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정맥 수율별 쌀보리의 수분흡수

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쌀보리(새쌀보리)의 주된 입자(7과 10 mesh 크기)를 무게비로 5%씩 30%까지 정맥하고 20-50℃에 침지시키면서 수분흡수속도를 분석하였다. 침지온도 40℃에서 평형수분함량에 도달하는 시간은 정맥율이 5-15%인 쌀보리의 경우에는 37% 정도 감소하였으며 정맥율이 20-30%인 경우에는 50%가 감소되었다. 정맥수율 95%인 쌀보리의 40℃에서의 수분흡수속도와 확산계수는 정맥하지 않은 시료보다 각각 1.5배와 2.8배 정도 빨랐다. 수분흡수의 활성화에너지값은 정맥수율이 5%씩 감소됨에 따라 약 0.4 kcal/mole 정도씩 감소되었다.