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Vacuum Effect on Milling Wheat

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Vacuum milling of wheat was used to prevent temperature rise of flour. We have used four vacuum pressure levels and one control pressure level (normal atmospheric pressure "1023.3 hPa"). Many factors of milling machine were measured. The consumption of power and the capacity of milling machine at different wheat moisture contents were determined. The milled flour moisture content was measured as well.

We concluded that the flour temperature after milling could be kept stable at a low level under vacuum pressure compared with the control. Milling power and moisture content of flour showed the same trend. Different levels of moisture contents seem to affect the milling machine capacity.

INTRODUCTION

In recent years there has been an interest among researchers to reduce the energy consumption to mill the high moisture brown rice. The energy consumption to mill the high moisture brown rice with heated air was significantly reduced when compared to control which were at storage-moisture milled with ambient air (Bekki and Kunze, 1988). The rice milling under vacuum has prevented quality reduction of milled rice with the rise of temperature. Rise in temperature can be perfectly prevented, and the effect of moisture content on the milled power per unit bran mass indicated that an increasing of the moisture content can decrease the milled power per unit bran mass in rice milling (Murata et *al.,* 1989). Attempts to develop a new system in order to enhance milling quality.

The vacuum drying process is a very effective method for removing moisture from freshly dug peanuts (Kunze et *al.,* 1968). Another study by (Murata and Nakamura, 1979) stated that, a sack of barley grains can be cooled by a vacuum cooler. The leafy vegetables and liquid foodstuffs can be rapidly cooled in adsorption driven vacuum coolers using hygroscopic brines (Yanniotis and Schwortzberg, 1986).

The overall objective of this research project was to determine the optimal initial moisture content of wheat to be milled under vacuum. The specific objectives of this research were to fiend out :

(1) The effect of vacuum milling on the milling power.
(2) The effect of vacuum milling on the temperature of flour soon after milling.
(3) The effect of vacuum milling on the moisture content of flour after milling.

MATERIALS AND METHODS

Special apparatus was designed for the experiment in Fig. 1, it is formed of a vacuum tank made of steel with specification 480 mm head and 418 mm diameter. The tank cover was designed to allow monitorring inside the vacuum tank. The vacuum tank contained a current supply to the milling machine, a place for measuring the vacuum inside the tank, place for connecting the vacuum pump, and another place for connecting thermocouple to measure the temperature inside the vacuum tank. The specifications for vacuum pump are Hitachi 4 VP-C3, pump speed 100L/min, R. P. M. 450, AC volts 100, motor output 200 w and AMP'S 5.5/4.8. The glass cold trap was connecting the vacuum pump to the vacuum tank to keep the vacuum pump at good condition when used. A manometer was connected directly with the vacuum tank. Also a recorder was connected to record the temperature during the experiment. A power meter was used to measure the milling power. The type of milling machine which placed inside the vacuum tank was Hikikko model no. K-180 product by Kansai Toki (Tokamachi Kikai Kogyo Co.) AC 100 v, 50/60 Hz and 230 w.

The experiments were conducted in the Laboratory of Agricultural Process

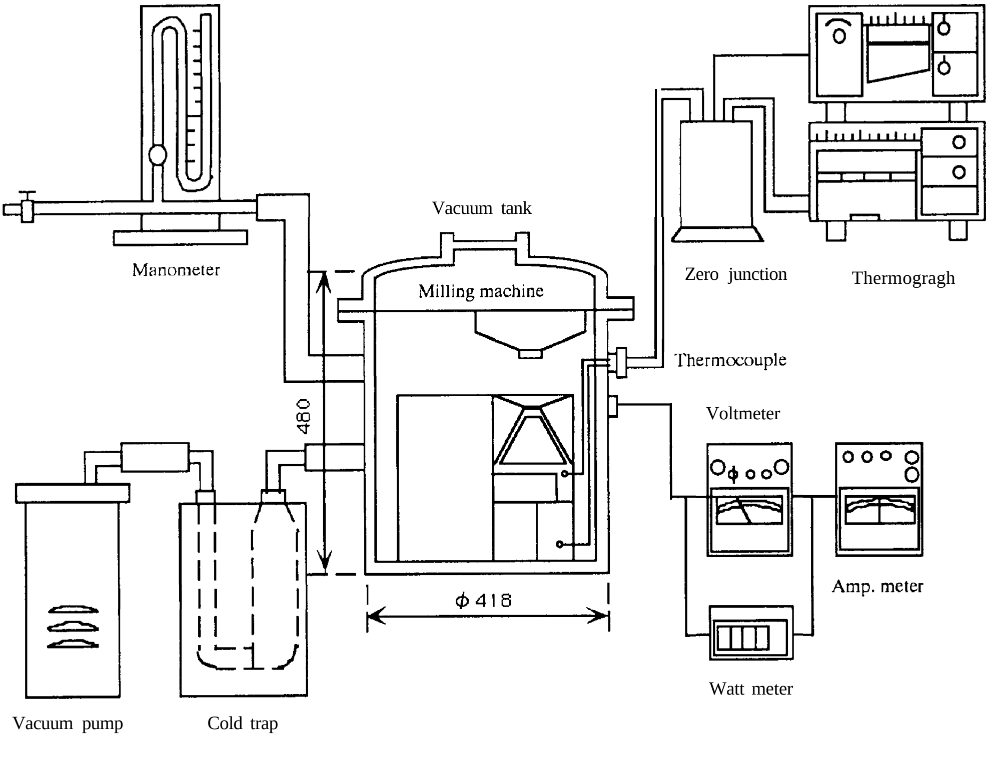

Fig. 1. Schematic diagram of vacuum milling apparatus.

Engineering Faculty of Agriculture, Kyushu University during winter season 1993 -1994.

Four vacuum levels and one control (normal atmospheric pressure) for six initial moisture contents of wheat were used. The normal atmospheric pressure of this experiment was ranging from 1020.7 hPa to 1028.8 hPa. The kind of wheat which used was "Western White" (this kind is a combination of White Club 10% and Soft White 90%).

The effects of initial moisture content on the milling power and milling power per unit mass were measured. The effects of vacuum level on the temperature of flour soon after milling were measured. We also used a hopper with small motor (10 v) to get constant feed rate for every experiment.

RESULTS AND DISCUSSION

Milling power

The milling power for wheat milling is shown in Fig. 2. The figure demonstrates, the effect of initial moisture content which were 13.4%, 14.6%, 16.2%, 18.3%, 19.4% and 20.2% (w. b.) on the milling power under different levels of vacuum pressure which were 340, 440, 540 and 640 mmHg below atmospheric pressure and one control (normal atmospheric pressure).

The results indicated that below initial moisture content of 16.2% the milling power increased with increasing the initial moisture content under all vacuum pressure levels, and the maximum milling power obtained at initial moisture content of 16.2%. Above 16.2% moisture content the milling power slightly decreased and rapidly increased again. The results also indicated that the milling power decreased with decreasing vacuum pressure.

Figure 3 shows the effect of the initial moisture contents on the milling power per unit mass. An increasing of initial moisture content decreased the milled power per

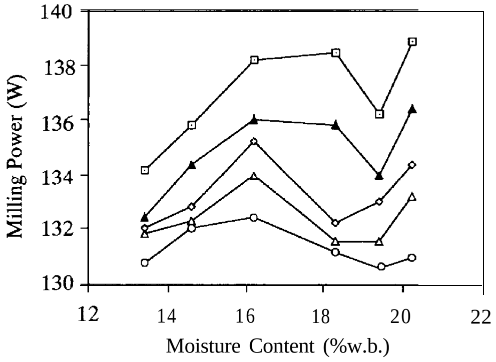

Fig. 2. Effect of moisture content of wheat on the milling power.
□ Control ▲ -340mmHg ◇ -440mmHg
△ -540mmHg ○ -640mmHg

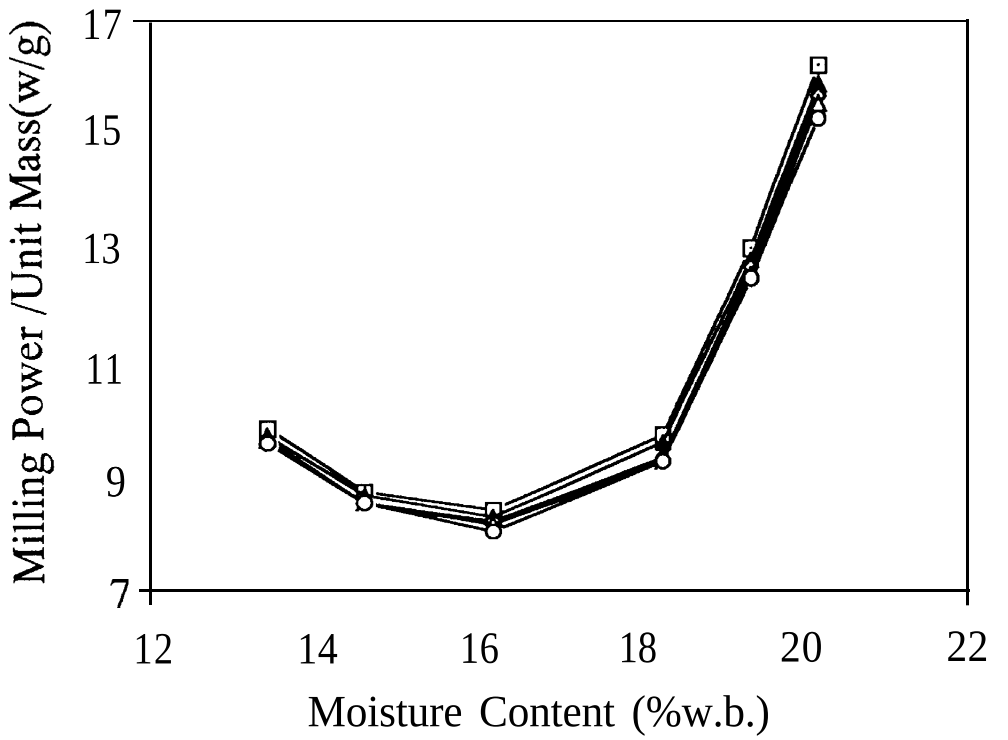

Fig. 3. Effect of moisture content of wheat on the milling power per unit mass.
⊡ Control ▲ -340mmHg ◇ -440mmHg
△ -540mmHg c -640mmHg

unit mass and the minimum milling power per unit mass obtained at the initial moisture content of 16.2%. Above 16.2% moisture content the milling power per unit mass rapidly increased. This is due to the decreasing of stiffness of wheat grains when initial moisture content increased from 13.4% to 16.2%. But when initial moisture content increased from 16.2% to 20.2% the milling power per unit mass increased due to the increasing of elasticity of wheat grains.

Feeding rate

Figure 4 shows the effect of initial moisture content on the feeding rate of wheat grains. The results indicated that the feeding rate increased with increasing initial moisture content from 13.4% to 16.2%. However, above 16.2% of initial moisture content the feeding rate decreased, this is due to the capacity of milling machine which increased from initial moisture content 13.4% to 16.2% and after the initial moisture content exceeded 16.2% the same amount of wheat grains took long time to mill.

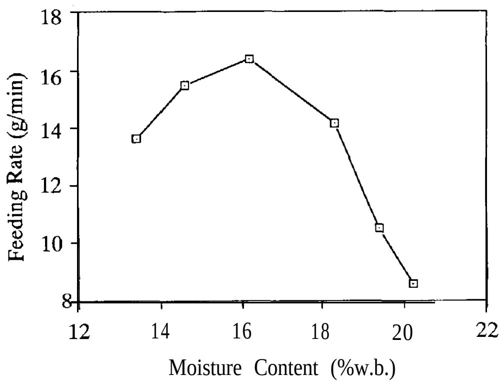

Fig. 4. Effect of moisture content on the feeding rate of wheat.

Moisture content of flour

Figure 5 shows the effect of initial moisture content of wheat on the moisture content of flour after milled. The results indicated that the moisture content of flour after milled slightly reduced compared with the initial moisture content of wheat grains before milling.

Figure 6 also shows the effect of vacuum pressure milling on the moisture content of flour after milling, the moisture content of flour after milling decreased with the decreasing of vacuum pressure from 340 to 640 mmHg below the normal atmospheric pressure. Also the drying rate of moisture content increased with increasing of the initial moisture content of wheat grains and with decreasing of the vacuum pressure heads below the control. This is due to the vacuum drying process which occurred by the decreasing of vacuum pressure head below the normal atmospheric pressure.

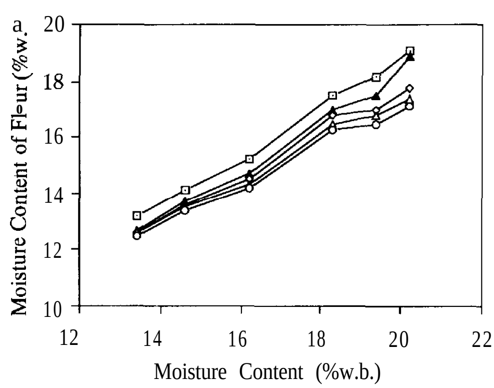

Fig. 5. Effect of moisture content of wheat on the moisture content of flour after milling.

❑ Control ▲ -340mmHg o -440mmHg
a -540mmHg o -640mmHg

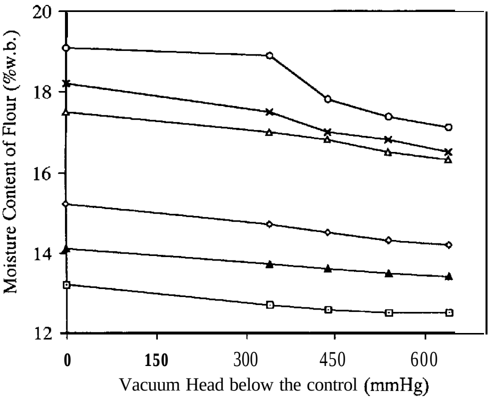

Fig. 6. Effect of Vacuum milling on the moisture content of flour after milling.
⊡ 13.4% ▲ 14.6% 0 16.2%
a 18.3% × 19.4% ○ 20.2%

Temperature

Figure 7 indicates that the effect of initial moisture content on the temperature of flour soon after milling. The increasing of initial moisture content of wheat grains from 13.4% to 20.2% had a little affect on the temperature of flour soon after milling.

Figure 8 shows the effect of vacuum pressure levels on the temperature of flour soon after milling. This figure indicated that decreasing of vacuum pressure head from 340 to 640 mmHg below the control decreased the temperature of flour soon after milling for all initial moisture content of wheat grains. This reduction of the temperature depends on refrigeration resulting from evaporation of water from the flour which lead to the reduction of the moisture content. Murata and Nakamura (1979) developed the following equation to determine the moisture content of flour after cooling :

$$m_2=(100\ C_o+m_1)[(\sigma_o-\varepsilon t_1)/(\sigma_o-\varepsilon t_2)]^{C_W/\varepsilon}-100\ C_o$$

where :

$C_0=C_d/C_W=0.2$

$C_d, C_W=$ 1.85 kJ/kg, 4.19 kJ/kg Specific heat for flour and water respectively

$m_1, m_2=$the moisture content before and after cooling

$\sigma_o=$latent heat of vaporization (2501 kJ/kg)

$t_1=$initial temperature (before cooling)

t_2 = temperature during cooling

ε =constant=2.34 kJ/kg.°C

As indicated in Fig. 8, at initial moisture content of 18.3% (w. b.) [22.4%(d. b.)] and 640 mmHg vacuum pressure the temperature before and after cooling were $t_1=12$°C and $t_2=9.7$°C then:

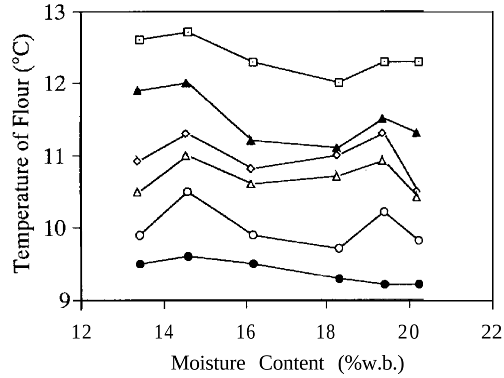

Fig. 7. Effect of moisture content of wheat on the temperature of flour soon after milling.
⊡ Control ▲ -340mmHg ◇ -440mmHg
△ -540mmHg ○ -640mmHg ● Grain temp.

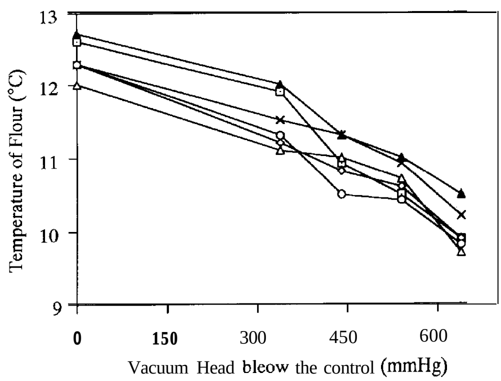

Fig. 8. Effect of Vacuum milling on the temperature of flour soon after milling.
⊡ 13.4% A 14.6% ◇ 16.2%
a 18.3% × 19.4% 0 20.2%

$$m_2=(100\times0.2+22.4)[(2501-2.34\times12.0)/(2501-2.34\times9.7)]^{4.19/2.34}-100\times0.2=22.1$$

The differences between m_1 and $m_2=22.4-22.1=0.3\%$ were very small as indicated in Fig. 6.

This reduction of the temperature would be good for the milling quality because oxidation, flavour loss and denaturation could be prevented for the flour after milling.

CONCLUSIONS

Four vacuum pressure levels were used successfully for wheat milling. The following conclusions are drawn from this study :

(1) milling power of wheat has a high sensitivity for the initial moisture content of wheat grains.
(2) milling power per unit mass decreases with the increasing of the initial moisture content.
(3) the initial moisture content of wheat has no effect or a little effect on the temperature of flour soon after milling.
(4) vacuum pressure head has a very strong effect on the milling power.
(5) vacuum pressure levels have affected the temperature of flour soon after being milled, it prevents the quality reduction.
(6) also vacuum pressure head has a slight effect on the moisture content of flour after millimg.
(7) finally the initial moisture content of wheat grains has a very important effect on the capacity of milling machine.

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