Oil Press for Food Oil and Biomass Production

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Abstract

In this study, first, rapeseed was separated the high quality seed for food oil and the low quality seed for biofuels. Next, laboratory-scale oilseed screw press was used to investigate the effects of choke opening and seed preheating on these rapeseed pressing performance and quality of food oil and biofuels oil. Maximum pressure increased, oil recovery increased, but chlorophyll in rapeseed oil was increased, too. Especially, acid value of the rapeseed oil extracted from low quality seed was high value. For the rapeseed pressing performance, the rapeseed heated by microwaves outputted more oil than that without heating. And the chlorophyll in the rapeseed oil extracted from the rapeseed treated by microwaves was higher than that without heating. The Net Energy Balance ratio of microwave heating press with choke opening set at 8.0 mm is advantage. And the oil pressed this method was good and basically fulfilled the Codex Alimentarius requirements for edible oils.

Keywords: *biomass, rapeseed, oil expression, microwave heating*

1. Introduction

The demand of domestically-produced rapeseed has been increasing in Japan. Civic groups and farmers cultivate the rapeseed for vegetable oil and alternative fuels production. And they are interested in feasibility of owned and operated rapeseed oil expression facilities. Technique for efficient expression of oil from oilseed is an important factor for small press used in these small scale oil expression facilities. Oilseed pretreatment by roasting is known to improve oil expression efficiency [1,2,3]. In addition, Oberndorfer *et al*. (1999) investigated oilseed pretreatment by microwave heating to influence oil expression. In this study, first, rapeseed was separated high quality seed for food oil and low quality seed for biofuels [4]. Next, laboratory-scale oilseed screw press was used to investigate effects of choke opening and seed preheating by microwaves on these rapeseed pressing performance and quality of food oil and biofuels oil.

2. Material and methods

Oilseed

Rapeseed, harvested from our experimental paddy field (June, 2009) and dried with a recirculation batch dryer, was used. This rapeseed was separated the high quality seed for food oil and the low quality seed for biofuels by an air classifier. Oil contents of the high quality seed (95% of the total seed) were 42 % and the low quality seed (5% of the total seed) were 40 %.

Laboratory press

A small scale oilseed press, Screw Press KEK-P0015 manufactured by EGON KELLER GMBH & Co. Kg in Germany, was used for experiments. This press has a 2.2 kW drive motor. In this study, standard press, two passes press and microwave heating press were experimented. In the standard press, the rapeseed for food was pressed with the choke opening set at 8.0 mm and 9.0 mm and the rapeseed for biofuels was pressed with the choke opening set at 8.0 mm. In the two passes press, first, the rapeseed was pressed with the choke opening set at 11.0 mm, next, oil cake generated from the first pass was pressed with the choke opening set at 8.0 mm. In the microwave heating press, the rapeseed was heated by a microwave applicator and pressed with the choke opening set at 8.0 mm and 9.0 mm. Prior to each experiment, the press was warmed up to a barrel temperature of about 50 ºC.

Expressed oil and oil cake were collected in an each weighing pan. The expressed oil was separated from 'foots' (solids expressed with oil) by centrifugation and weighed. In the each filtration oil samples, following parameters were determined. Acid value (AV) expressed in mg KOH per g of oil was determined according to ISO 660:2009. Chlorophyll pigments were determined by a visible-ultraviolet spectrophotometer according to Standard Methods for the Analysis of Fats, Oils and Related Materials established by Japan Oil Chemists' Society, where chlorophyll (pppm) = $(A_{670}-1/2(A_{630}+A_{710}))/0.0964$. Induction time was determined with Rancimat test in 120 ºC according to ISO6886:2006.

Microwave heating

The most widely used microwave oven adopts multi-mode microwave irradiation. Using the multi-mode, microwaves are irradiated randomly and unsteadily in an applicator. In contrast, a single-mode microwave applicator uses a standing wave in a waveguide and can efficiently heat a material. A guide wavelength in a rectangular waveguide is derived from Eq. (1). Furthermore, displacement of the composite wave (incident wave and reflected wave) at a fixed end is derived from Eq. (2). A nearest node from the fixed end is located in $\lambda_g/2$ from the fixed end; the distance between nodes is $\lambda_g/2$. Therefore, by moving the short circuit plate $\lambda_g/4$ ($\fallingdotseq$43 mm; frequency: 2.45 GHz), a point of maximum amplitude of the standing microwave is shifted (Fig. 1). For this study, the material was irradiated with microwaves using an adjustable short circuit plate. The adjustable short circuit plate was moved intermittently with stopping for 1 s from 0 mm to 43 mm. Figure 2 portrays an experimental single-mode microwave applicator. This application unit is equipped with a magnetron (2M251; Hitachi Kyowa Engineering Co., Ltd.), an isolator, a power monitor, a rectangular waveguide applicator (W86.36 mm, H43.18 mm, IEC-WR-340) and an adjustable short circuit plate. The isolator absorbs reflected microwaves. The reflectivity coefficient Γ^2 (reflected power / incident power) was measured using the power monitor (EPM E4419A; Agilent Technologies, Inc.). A fluorescent optical fiber thermometer (FL-2000; Anritsu Corp.) was used to measure the temperature of the rapeseed after microwave irradiation. The rapeseed was put in a hopper and continuously heated by microwaves in the wave guide applicator. The heated rapeseed was conveyed to the screw press by a screw feeder.

$$\lambda_g = \frac{\lambda}{\sqrt{1-\left(\frac{\lambda}{\lambda_c}\right)^2}} \qquad \because \lambda_c = 2a \tag{1}$$

$$Y = Y_1 + Y_2 = 2A\cos 2\pi f A\left(t-\frac{L}{v}\right)\sin 2\pi f\left(\frac{L-z}{v}\right) \tag{2}$$

In that equation, the following are used.

λ_g : guide wavelength, λ : free space wave length, λ_c : cutoff wavelength

a : width of rectangle waveguide, Y : compound displacement

Y_1 : displacement of incident wave, Y_2 : displacement of reflected wave

f : frequency, v : wave speed, L : lenght of waveguide

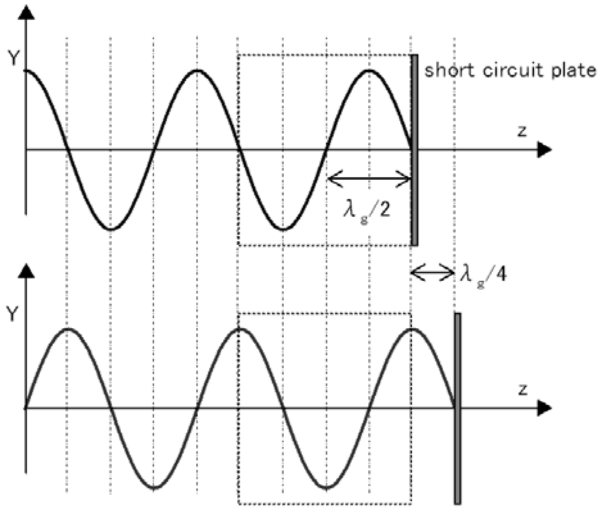

Fig. 1 Phase variation at the fixed end

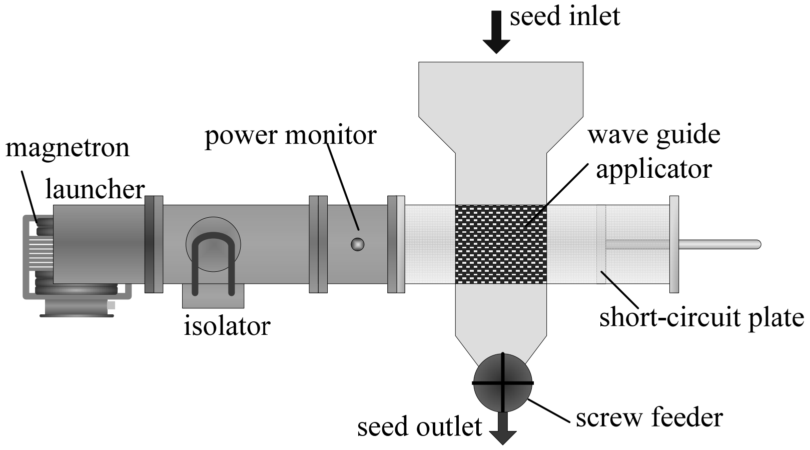

Fig. 2 Schematic diagram of the experimental single-mode microwave applicator

3. Results and discussions

Microwave heating

In the microwave irradiation experiment, the rapeseed was irradiated with moving the adjustable short circuit plate. The rapeseed temperature and incident power for rapeseed, reflected power from rapeseed and absorbed power into rapeseed are indicated in figure 3. The rapeseed was heated at about 112 ºC continuously by the microwave applicator. Then average incident power for rapeseed was 2.80 kW and the average reflected power from rapeseed was 0.47 kW. The average reflectivity coefficient Γ^2 was 0.17. The active power used for the rapeseed heating by this microwave applicator was 3.8 kWh. So, in this microwave applicator, overall microwave absorption efficiency (absorbed power into rapeseed / supplied power for microwave applicator × 100) was 74%.

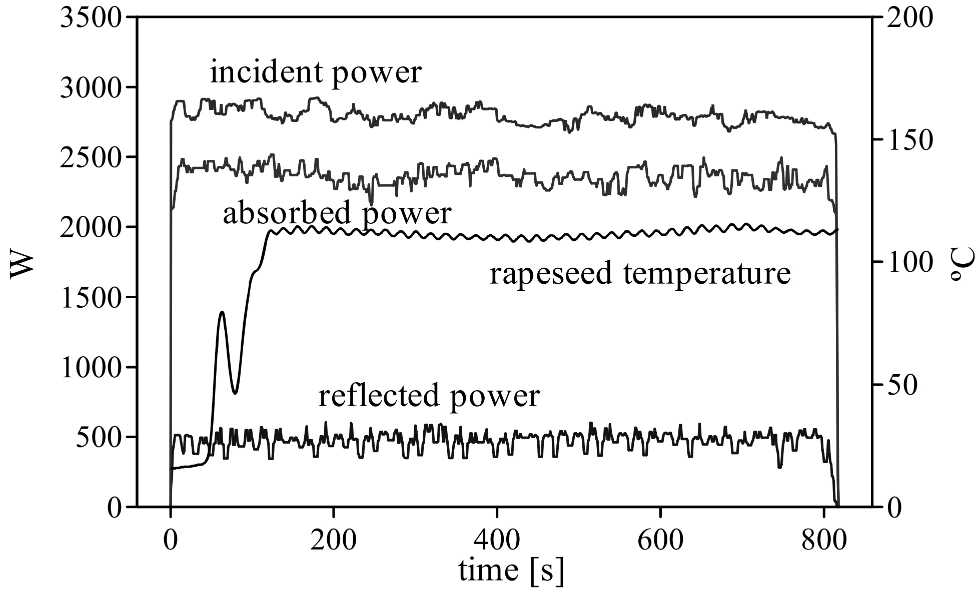

Fig. 3 Rapeseed temperature and incident, reflected and absorption power of microwaves

Comparison of standard press, two passes press and microwave heating press

Table 1 presents the mean values of percent oil recovery, oil productivity and specific energy consumption corresponding to different methods of press and choke opening. In respect of the standard press experiments, the more choke opening was narrow, the more oil recovery increased. But the oil productivity became less efficient and specific energy consumption increased as the choke opening was narrow. In respect of the two passes press experiments, the oil recovery was 17.9% at the first pass. The oil cake generated from the first pass included 29.7% of oil. When the second pass, 7.4% of oil recovered from the oil cake. So, the total oil recovery was 24.0%. Oil productivity of 4.1 L/h was most inefficient among the six press methods. In respect of the microwave heating press experiments, the more choke opening was narrow, the more oil recovery was increase, too. From among the six presses considered, the maximum oil recovery of 28.7% was observed in the microwave heating press with choke opening set at 8.0 mm, but specific energy consumption was highest among the six presses methods. In the oil productivity, microwave heating press with choke opening set at 9.0 mm was most efficiency. Table 2 presents the mean values of acid value, chlorophyll pigments and induction time at 120 ºC in Rancimat test. In respect of the acid value, there was no great distinction from press method. But the acid value of oil expressed from low quality seed was higher. It results from the fact that, in the low quality seed included damaged seed, a lipase activity into seed increased during storage, and the lipid was hydrolyzed. Chlorophyll pigments of oil expressed from the microwave heating experiments were higher value than other press methods. In addition that the oil from pressed with choke opening set at 8.0 mm shows a higher value than the oil from pressed with choke opening set at 9.0 mm in any press methods. Matgorzata *et al.* discussed that a low content of chlorophyll expressed was observed in cold press (same as the standard press) compared to virgin pressed from preheated seeds (100 ºC, 40 min) [5]. In this study, chlorophyll pigments of oil increased by preheating with microwaves and high pressure pressing. The Rancimat test showed that highest oxidative stability was characteristic for standard pressed oil from low quality seed, second pressed oil in two passes press and microwave heating pressed oil. The quality of oils from standard pressed, two passes pressed and microwave heating pressed was good and basically fulfilled the Codex Standard for edible oils except the oil pressed from low quality seed.

Table 1 Oil recovery, oil productivity and energy consumption

	choke opnening, mm	oil recovery, %	oil productivity, L/h	energy consumption, MJ/kg_seed
standard press (high quality seed)	9.0	20.5	5.9	0.52
	8.0	21.2	5.2	0.61
standard press (low quality seed)	8.0	16.2	4.8	0.50
two passes press total	11.0 and 8.0	24.0	4.1	0.76
microwave heating press	9.0	23.2	6.4	0.86
	8.0	28.7	5.7	0.97

Table 2 Acid value, chlorophyll pigments of oil and induction time in Rancimat test

	choke opnening, mm	acid value	chlorophyll pigments, ppm	Induction time at 120 ºC in Rancimat test, h
standard press (high quality seed)	9.0	3.3	7.6	2.8
	8.0	3.2	8.1	2.8
standard press (low quality seed)	8.0	22.2	10.8	3.6
two passes press, 1st pass	11.0	3.5	7.9	2.6
, 2nd pass	8.0	3.6	10.6	3.2
microwave heating press	9.0	3.3	35.0	3.2
	8.0	3.2	36.0	3.6

Evaluation of bio energy

The evaluation of the biodiesel made from the rapeseed oil was investigated. Farm energy inputted rapeseed production estimates 1.9MJ/kg$_{_seed}$. The energetic and chemical consumptions of the transesterification of rapeseed oil are 2.0MJ/kg$_{_oil}$ [6]. A gross heating value of biodiesel is 39.8 MJ/kg. Net Energy Balance ratio (NEB ratio = energy output / energy input) of biodiesel production with each press methods are indicated in figure 4. The standard press for low quality seed has a high NEB ratio because of the farm energy is not included. In contrast, standard press for high quality seed, two passes press and microwave heating press with choke opening set at 9.0 mm has a low NEB ratio. The NEB ratio of microwave heating press with choke opening set at 8.0 mm is advantage except the low quality seed press.

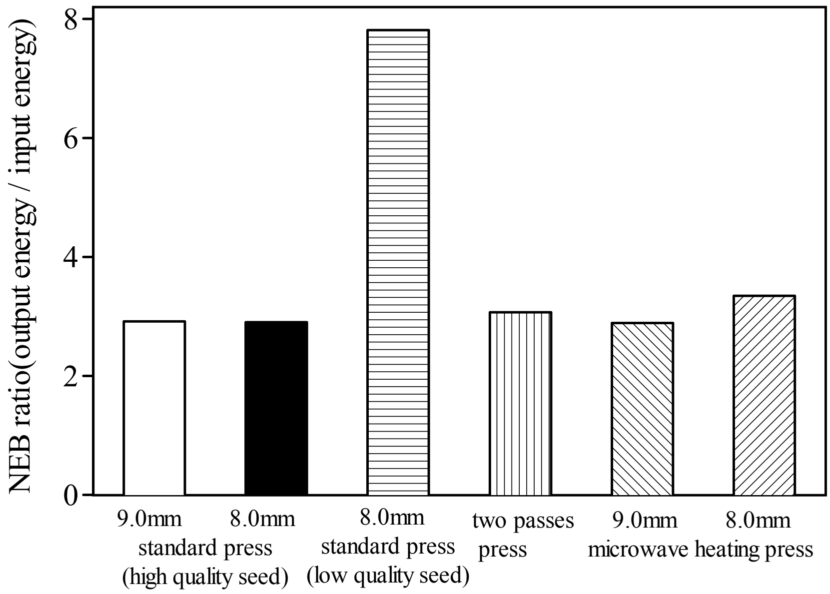

Fig. 4 Net Energy Balance Ration for Biodiesel Production

4. Conclusion

In the small oil expression facilities on farms, technique for efficient expression of oil from oilseed is an important factor for vegetable oil production and bio fuel production. The six different methods of oil pressing were considered. Consequently, rapeseed was heated efficiently by single mode microwave applicator. Oil recovery and NEB ratio for biodiesel production of the microwave heating press with choke opening set at 8.0 mm was advantage.

References

[1] L.M. Khan and M.A. Hanna. 1983. Expression of Oil from Oilseeds -- A Review. **J. Agric. Engng. Res.** 28: 495–503.

[2] C.L. Peterson, D.L. Auld and J.C. Thompson. 1983. Experiments with Vegetable Oil Expression. **Transactions of the ASAE**, 1298–1302.

[3] Vivek S. Vadke and F.W. Sosulski. 1988. Mechanics of Oil Expression from Canola. **JAOCS**, 65(7): 1169–1176.

[4] Oberndorfer C. and Lücke W. 1999. The effect of rapeseed treatment by microwave and radio-frequency application on oil extraction and oil quality. Part 1: Influence on mechanical oil extraction. **Fett/Lipid** 101(5): 164–167.

[5] Hubert Halleux, Stephane Lassaux, Robert Renzoni and Albert Germain. 2008. Comparative Life Cycle Assessment of Two Biofuels Ethanol from Sugar Beet and Rapeseed Methyl Ester. **Int J LCA**, 13(3): 184-190

[6] Matgorzata Wroniak, Krzysztof Krygier, Marzena Kaczmarczyk. 2008. Comparison of the quality of cold pressed and virgin rapeseed oils with industrially obtained oils. **Pol. J. Food Nutr. Sci.** 58(1): 85-89