Effect of Wax Content on Flow Properties of Rice Bran Oil

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Viscosity of crude rice bran oil with the wax content of 0.23–8.60 (% wt/wt) was measured using a coaxial cylindrical viscometer in the temperature range of 297–333 K. The crude oil behaved like pseudoplastic fluid obeying power law with consistency index $k = 2.0187 \times 10^{-4} c^{0.2066} e^{2815/T}$ and flow behavior index n = 0.76, where c is the wax content and T is the temperature in Kelvin. Soy lecithin in the range of 1–2% did not affect the rheological properties.

Crude rice bran oil during refining has to undergo a number of unit operations, namely, fluid flow, heat transfer and separation of gums and waxes. Knowledge of the rheological behavior of the oil is essential for design of the processing equipment. This study is aimed at determining the flow characteristics of crude rice bran oil at different temperatures and concentrations of the suspended and/or dissolved materials.

MATERIALS AND METHODS

Crude rice bran oil, with composition as indicated in Table 1, obtained from a local solvent extraction plant was degummed, dewaxed and refined. Degumming was carried out at the temperature of 353 K with 3% water and 0.5% phosphoric acid (1). Refining was done according to the American Oil Chemists' Society official method (2). Dewaxing was done by repeated centrifugations using a Westfalia laboratory separator (type LWA 205) to get an oil containing 0.23% wax. Test solutions for viscosity measurements were prepared by mixing crude wax obtained during centrifugation of degummed oil with the refined oil in different proportions (Table 2). Commercial soy lecithin of 45% purity was mixed with refined oil to get samples containing 1.0, 1.5 and 2.0% lecithin. Wax was estimated by the method of Kumar David et al. (3) Free fatty acid and fatty acid composition was carried out according to the AOCS method (2).

A coaxial cylindrical viscometer Rheotest 2 (VEB MLW) with radius ratio of 0.81 was used for determining shear stress (τ in dyne/cm²) at 12 different shear rates (du/dy) ranging from 1/6–145.8 sec⁻¹, and at five different temperatures for samples with different wax and soy lecithin contents.

Regression analyses of the four model systems were done by the method of least squares using a computer.

TABLE 1

Composition of Rice Bran Oil

	Percentage composition
Free fatty acids (% oleic acid)	6.3
Wax content (% wt/wt)	4.0
Fatty acid	
Lauric	0.2
Myristic	0.2
Palmitic	21.6
Stearic	2.0
Arachidic	0.6
Total saturated	24.6
Palmitoleic	0.3
Oleic	42.9
Linoleic	31.1
Linolenic	1.1
Total unsaturated	75.4

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RESULTS AND DISCUSSION

Crude oil behaves like a pseudoplastic fluid and obeys the power law model $\tau = k(du/dy)^n$, where k is the consistency index and n is the flow behavior index. The data of shear stress vs shear rate showed a high degree of correlation (Table 3). The value of k decreases with an increase in the temperature (T) and follows Arrhenius model $k = k_\infty e^{E/RT}$, where k_∞ is the Arrhenius constant, E is the activation energy and R is the universal gas constant. The wax content has a significant effect on the consistency index (Table 3), and its effect on k_∞ follows the relation $k_\infty = Ac^B$, where A and B are constants. Lecithin (1-2%) does not influence the values of k and n (Table 4). Table 5 shows the values of the parameters of the various models along with their correlation coefficients.

In conclusion, the apparent viscosity (μ_a in poise) of crude rice bran oil increases with the concentration of wax and decreases with the temperature, which can be

TABLE 2

Wax and Free Fatty Acid Contents of Test Solutions

Sample no.	Wax (% wt/wt)	Free fatty acid (as % oleic acid)
1	0.23	1.7
2	0.63	2.2
3	1.25	2.4
4	3.10	2.8
5	5.70	3.7
6	8.60	4.3

TABLE 3

Effect of Wax Content and Temperature on Rheological Parameters

Wax (% wt/wt)	Temp (K)	n	k (dyne.s^n/cm^2)	Correlation coefficient for power law	E/R (K)	$k_\infty \times 10^4$ (dyne.s^n/cm^2)	Correlation coefficient for Arrhenius model
0.23	297	0.790	1.878	0.981	2819	1.45	0.944
	303	0.786	1.600	0.986			
	313	0.769	1.390	0.976			
	323	0.750	1.062	0.975			
	333	0.714	0.830	0.990			
0.63	297	0.781	2.411	0.978	2816	1.92	0.986
	303	0.778	2.096	0.990			
	313	0.778	1.492	0.979			
	323	0.744	1.270	0.969			
	333	0.727	1.020	0.865			
1.25	297	0.786	2.460	0.998	2809	1.98	0.948
	303	0.750	1.896	0.920			
	313	0.739	1.433	0.935			
	323	0.763	1.221	0.981			
	333	0.739	1.067	0.931			
3.10	297	0.748	3.387	0.931	2816	2.65	0.929
	303	0.748	2.886	0.979			
	313	0.742	2.117	0.985			
	323	0.700	1.878	0.972			
	333	0.688	1.507	0.976			
5.70	297	0.784	3.525	0.994	2811	2.68	0.999
	303	0.786	2.886	0.999			
	313	0.769	2.226	0.996			
	323	0.768	1.568	0.986			
	333	0.768	1.246	0.982			
8.60	297	0.778	5.053	0.997	2819	3.34	0.966
	303	0.783	4.015	0.994			
	313	0.783	2.612	0.999			
	323	0.786	1.804	0.998			
	333	0.758	1.553	0.991			
Average		0.759		0.974	2185		0.962
Standard deviation		0.0026		0.029	3.786		0.0238

TABLE 4

Effect of Soy Lecithin on Power Law Constants

Lecithin in crude oil (% wt/wt)	297 K		303 K	
	k (dyne.s^n/cm^2)	n	k (dyne.s^n/cm^2)	n
0.0	1.878	0.790	1.600	0.786
1.0	1.878	0.780	1.600	0.784
1.5	1.870	0.790	1.610	0.788
2.0	1.879	0.789	1.609	0.790

TABLE 5

Correlation Coefficients of the Different Models

Model	Values of the parameters	Correlation coefficient
$\tau = k(du/dy)^n$	n = 0.759	0.974
$k = k_\infty e^{E/RT}$	E = 5593 cal /g.mole R = 1.987 cal/g.mole K	0.962
$\kappa_\infty = Ac^B$	A = 2.0187×10^{-4} dyne.s^n/cm^2 B = 0.2066	0.974
$k = Ac^B e^{E/RT}$	A = 2.0187×10^{-4} dyne.s^n/cm^2 B = 0.2066 E/R = 2815 K	0.957

calculated using the following expression obtained by combining the models given in Table 5:

$$\begin{aligned}\mu_a &= \tau/(du/dy)\\ &= k(du/dy)^{n-1}\\ &= Ac^{B}e^{E/RT}\,(du/dy)^{n-1}\\ &= 2.0187 \times 10^{-4}c^{0.2066}e^{2815/T}\,(du/dy)^{-0.24}\end{aligned}$$

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