DETERMINATION OF OIL YIELD, THROUGHPUT AND EXTRACTION LOSS OF RAPE AND CAMELINA BULK SEEDS USING A MINI SCREW PRESS

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Abstract

This study evaluated the oil yield, throughput and extraction loss of bulk rapeseeds and camelina seeds of varying sample input weights ranging from 50 g to 450 g using a mini screw press. Based on the results obtained, the oil yield of bulk rapeseeds ranged from 14.54 to 24.76 % whereas the oil yield of camelina seeds ranged from 17.76 to 24.94 %. The throughput for rapeseeds ranged from 1.20 to 2.40 kg/h, and that of the camelina seeds ranged from 1.00 to 2.45 kg/h. The extraction loss during the pressing process for rapeseeds ranged from 1.34 to 7.81 % whereas that of camelina seeds ranged from 0.81 to 5.63 %. The total oil yield of rapeseeds was 24.66 % compared to the total oil yield of 24.87 % for camelina seeds, indicating that camelina seeds possess a higher oil yield than rapeseeds. The corresponding total throughput for rapeseeds was 2.23 kg/h, whereas camelina seeds offered 2.01 kg/h.

Keywords: *Bulk oilseeds; input sample weight; oil extraction, mechanical screw press, seedcake output*

INTRODUCTION

Oilseed crops such as soybean, cottonseed, peanut, camelina, canola or rapeseed, safflower, mustard and sunflower, refer to the crops mainly grown for the oils in their seeds, that is, vegetable oils, which are used in various applications such as cooking and biodiesel production (*Yong and Wu, 2022; Bujnovský, Holíčková & Ondrejíčková, 2020; Embaye et al., 2018*). In this study, attention is given to rapeseeds and camelina seeds. Rapeseed (*Brassica napus*), commonly referred to as canola, is an oil-rich crop containing approximately 40-50% oil (*Cisneros-Yupanqui et al., 2023; Chmielewska et al., 2021*). It belongs to the Brassicaceae family, which includes three primary species: *Brassica napus*, *Brassica rapa*, and *Brassica juncea* (*Lin et al., 2013*). Camelina (*Camelina sativa* L.) seeds contain oil that makes up approximately 30-46% of their composition, with 80-90% of the fatty acids in the oil being unsaturated. This includes a significant proportion of α-linolenic acid (30-40%), an omega-3 fatty acid beneficial for human and animal nutrition (*Campbell et al., 2013; Moser 2012*). Edible oil production from seeds involves several unit operations, including cleaning, conditioning, extraction and refining (*Dunfold, 2022; Krapf, 2021*). Mechanical pressing, such as a screw press, is commonly used for oil extraction, although yields are significantly lower compared to hexane extraction, which results in very high oil yields of about 99% but there are concerns of potential environmental risks (*Gaber, Tujillo, Mansour & Juliano, 2018*). Continuing research on the improvement of the mechanical pressing system in terms of oil extraction efficiency is crucial. Therefore, the present study examined the oil yield, throughput and extraction loss of rape and camelina oilseeds by using a mini screw press with varying input sample weights between 50 and 450 g.

MATERIALS AND METHODS

Samples of bulk rapeseeds and camelina seeds were used for the study. The samples were purchased from Stredi, Prague, Czech Republic. Before the experiments, the samples were kept under laboratory conditions. The moisture content of the samples was determined using equation (1) (*Blahovec, 2008*).

$$MC = \left[\left(\frac{m_b - m_a}{m_b}\right) \cdot 100\right] \quad (1)$$

where MC is the percentage moisture content of the sample (% w.b.), m_a and m_b are the masses of the sample before and after oven drying (g). The mini screw press - Yoda Electric Oil Press (Model: YDZY02A1; Naarden, The Netherlands) (*Kabutey et al., 2022*) was used for extracting the oil from the rape and camelina seeds, weighing between 50 g and 450 g with 50 g intervals. The electronic balance Kern 440-35 (Kern & Sohn GmbH, Balingen, Germany) with an accuracy of 0.01 g was used for weighing the samples of rapeseeds and camelina seeds. For each extraction process, the oil press was preheated for 15-30 seconds. A digital stopwatch was used for recording the pressing time. The oil yield was determined using equation (2) (*Chanioti & Tzia, 2017*).

$$O_{YD} = \left[\left(\frac{M_{OL}}{M_{SP}}\right) \cdot 100\right] \qquad (2)$$

where O_{YD} is the oil yield (%), M_{OL} is the mass of oil determined as the difference between the mass of the seedcake and the initial mass of the sample, M_{SP} (g). The throughput was calculated as the ratio of sample weight (g) to that of the extraction time (min) (*Karaj and Muller, 2011*). The extraction loss was calculated following the mathematical (*Alenyorege, Hussein & Adongo, 2015*). The whole extraction process of the samples is shown in Figs. 1 and 2.

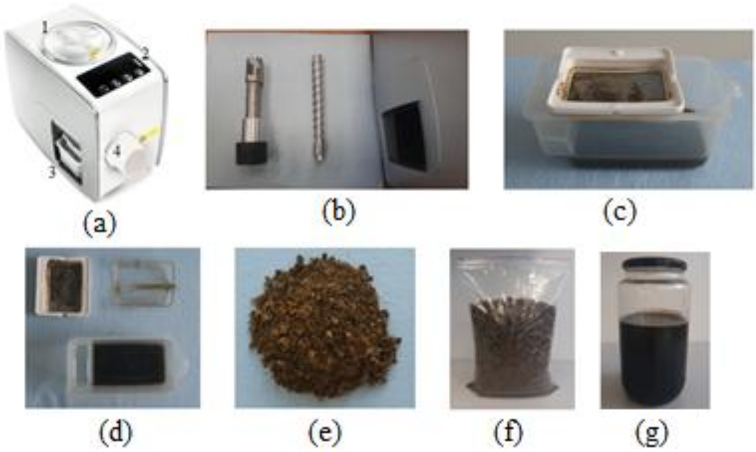

Fig. 1 (a) Yoda electric oil press; 1: Hopper; 2: Pre-programmed settings for different types of seeds/nut; 3: Oil flow chamber and 4: Seedcake exit through the screw cage pin; (b) Screw and cage; (c and d) Press components for obtaining the crude oil; (e) Rapeseed cake; (f) Packed seedcake and (g) Extracted crude rapeseed oil.

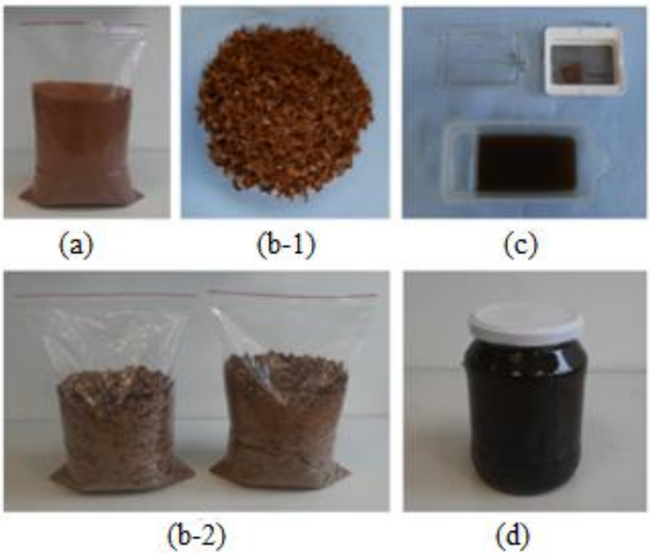

Fig. 2 Oil extraction process of (a) camelina seeds, (b-1 and b-2) pressed or seedcake cake, (c) press components for collecting the oil and (d) extracted camelina oil.

RESULTS AND DISCUSSION

The moisture content of rapeseeds was determined to be 5.25 ± 0.23 (% w.b.), whereas that of camelina seeds was 6.00 ± 0.33 (% w.b.). According to *Singh and Bargale 1990*, the increase in moisture content of soaked and sun-dried flaxseeds from 5 to 7 % d.b. increased the oil yield, but at 9 % d.b. moisture content, the oil yield decreased. *Sing et al., 2002* also reported that the decrease in moisture content from 9.2 to 3.6 % d.b. increased the oil recovery of cooked and uncooked crambe seeds. In the screw pressing operation, higher moisture content increases plasticity, thereby reducing the level of compression and contributing to poor oil recovery (*Singh and Bargale, 1990*). The results of the oil extraction parameters of rapeseeds and camelina seeds under mini-screw pressing operation are provided in Tabs. 1 to 3, respectively. The main parameters calculated from the samples' weights ranging from 50 g to 450 g were the oil yield, throughput and extraction loss. The mass of oil for rapeseeds ranged from 7.27 to 111.42 g, with the corresponding oil yield values ranging from 14.54 to 24.76 %. The throughput values ranged from 1.20 to 2.25 kg/h, and the values of the extraction loss (oil and seedcake sediments) ranged from 1.36 to 5.62 %. In comparison with camelina seeds, the mass of oil ranged from 8.88 to 112.22 g, with the corresponding oil yield values ranging from 17.76 to 24.94 %. The throughput values ranged from 1.00 to 2.45 kg/h. The extraction loss values ranged from 0.76 to 1.68 %. The total pressing times were 60.5 min for rapeseeds and 67 min for camelina seeds.

Tab. 1 Calculated oil extraction parameters from rapeseeds under mini-screw pressing.

Sample weight (g)	Seedcake (g)	Mass of oil (g)	Oil yield (%)	Pressing time (min)	Throughput (g/min)	Throughput (kg/h)
50	41.39	7.27	14.54	2.5	20.0	1.20
100	71.28	23.10	23.10	3	33.3	2.00
150	108.22	35.93	23.95	4	37.5	2.25
200	145.27	50.41	25.21	5	40.0	2.40
250	182.25	62.13	24.85	7	35.7	2.14
300	218.31	77.21	25.74	8	37.5	2.25
350	256.32	86.19	24.63	9	38.9	2.33
400	293.39	101.17	25.29	10	40.0	2.40
450	330.77	111.42	24.76	12	37.5	2.25

Tab. 2 Calculated oil extraction parameters from camelina seeds under mini-screw pressing.

Sample weight (g)	Seedcake (g)	Mass of oil (g)	Oil yield (%)	Pressing time (min)	Throughput (g/min)	Throughput (kg/h)
50	40.31	8.88	17.76	3	16.70	1.00
100	76.69	22.55	22.55	4	25.00	1.50
150	111.44	36.4	24.27	5	30.00	1.80
200	147.89	50.09	25.05	6	33.30	2.00
250	183.52	64.18	25.67	8	31.30	1.88
300	220.89	74.07	24.69	8	37.50	2.25
350	256.45	89.29	25.51	10	35.00	2.10
400	294.85	101.95	25.49	12	33.30	2.00
450	332.15	112.22	24.94	11	40.90	2.45

Tab. 3 Calculated extraction loss of rapeseeds and camelina seeds under mini-screw pressing.

Sample weight (g)	Rapeseeds		Camelina seeds	
	* Total sample weight (g)	* Extraction loss (g); (%)	* Total sample weight (g)	*Extraction loss (g); (%)
50	48.66	1.34 (2.68)	49.19	0.81 (1.62)
100	94.38	5.62 (5.62)	99.24	0.76 (0.76)
150	144.15	5.85 (3.90)	147.84	2.16 (1.44)
200	195.68	4.32 (2.16)	197.98	2.02 (1.01)
250	244.38	5.62 (2.25)	247.70	2.30 (0.92)
300	295.52	4.48 (1.49)	294.96	5.04 (1.68)
350	342.51	7.49 (2.14)	345.74	4.26 (1.22)
400	394.56	5.44 (1.36)	396.8	3.20 (0.80)
450	442.19	7.81 (1.74)	444.37	5.63 (1.25)

* Extracted crude oil and seedcake/sediment.

The descriptive statistics and the single-factor ANOVA results of the calculated parameters of the samples of rapeseeds and camelina seeds under mini-screw pressing are provided in Tabs. 4 to 7, respectively. The total mass of oil for the rapeseeds sample, weighing between 50 and 450 g, was 554.83 g compared to camelina seeds, which recorded 559.63 g. Relating these values to the total sample weights, the total oil yield of rapeseeds was 24.66 % compared to the total oil yield of 24.87 % for camelina seeds, indicating that camelina seeds contain a slightly higher oil yield than rapeseeds under the same processing conditions. The single-factor ANOVA results indicated that sample weight had a significant effect (F-value > F-critical or P-value < 0.05) on the calculated parameters of rapeseeds and camelina seeds, respectively.

Tab. 4 Descriptive analysis of rapeseed oil extraction parameters.

Parameters	Count	Sum	Average	Variance
W_{t_RP} (g)	9	2250	250	18750
M_{O_RP} (g)	9	554.83	61.65	1264.32
O_{Y_RP} (%)	9	212.07	23.56	12.05
L_{S_RP} (%)	9	23.34	2.59	1.86
T_{P_RP} (kg/h)	9	19.23	2.14	0.14

W_{t_RP}: Sample weight of rapeseed; M_{O_RP}: Mass of oil; O_{Y_RP}: Oil yield; L_{S_RP}: Extraction loss; T_{P_RP}: Throughput and *RP*: Rapeseed.

Tab. 5 Results of single-factor ANOVA analysis of rapeseeds oil extraction parameters.

Sources of variation	Sum of squares	Degrees of freedom	Mean square	F-value	P-value	F-critical
Between Groups	393796.137	4	98449.03	24.577	< 0.05	2.606
Within Groups	160226.966	40	4005.67			
Total	554023.103	44				

F-value > F-critical or P-value < 0.05 means significant

Tab. 6 Descriptive analysis of camelina seeds oil extraction parameters.

Parameters	Count	Sum	Average	Variance
W_{t_CL} (g)	9	2250	250	18750
M_{O_CL} (g)	9	559.63	62.18	1273.52
O_{Y_CL} (%)	9	215.92	23.99	6.36
L_{S_CL} (%)	9	10.70	1.19	0.12
T_{P_CL} (kg/h)	9	16.98	1.89	0.18

W_{t_RP}: Sample weight of rapeseed; M_{O_CL}: Mass of oil; O_{Y_CL}: Oil yield; L_{S_CL}: Extraction loss; T_{P_CL}: Throughput and *CL*: Camelina.

Tab. 7 Results of single-factor ANOVA analysis of camelina seeds oil extraction parameters.

Sources of variation	Sum of squares	Degrees of freedom	Mean square	F-value	P-value	F-critical
Between Groups	395363.294	4	98840.824	24.673	< 0.05	2.606

Within Groups	160241.436	40	4006.036
Total	555604.73	44	

F-value > F-critical or P-value < 0.05 means significant

In Tab. 8, the observed, predicted and residual values of oil yield of rapeseeds and camelina seeds. The simple linear regression models as a function of the predictor variable, sample weight, W_t for predicting the observed values of oil yield, O_{YD} of rapeseeds and camelina seeds are described in equations (3) and (4).

$$O_{YD}(\%)rapeseed = 19.452 + 0.016 * W_t \quad (3)$$

$$O_{YD}(\%)camelina = 20.686 + 0.013 * W_t \quad (4)$$

It was noticed that the coefficient of the sample weight for rapeseeds was not significant (P-value > 0.05) whereas the intercept coefficient was significant (P-value < 0.05). In the case of the camelina seeds regression model, all the coefficients were significant, which produced lower residual values indicating less variation in the observed data compared to the residual values of rapeseeds oil yield, which had a slightly higher variation in the observed data. The coefficient of determination (R^2) values of the regression models ranged between 0.42 and 0.52.

Tab. 8 Observed, predicted and residual values of oil yield of rapeseeds and camelina seeds.

Oil yield (%) of rapeseed			Oil yield (%) of camelina		
Observed	Predicted	Residual	Observed	Predicted	Residual
14.54	20.27	-5.73	17.76	21.35	-3.59
23.10	21.10	2.00	22.55	22.01	0.54
23.95	21.92	2.03	24.27	22.67	1.60
25.21	22.74	2.46	25.05	23.33	1.71
24.85	23.56	1.29	25.67	23.99	1.68
25.74	24.39	1.35	24.69	24.65	0.04
24.63	25.21	-0.58	25.51	25.31	0.20
25.29	26.03	-0.74	25.49	25.97	-0.49
24.76	26.85	-2.09	24.94	26.64	-1.70

CONCLUSIONS

Oil extraction from samples of rapeseeds and camelina seeds was examined using a mini screw press. The weight of the samples varied between 50 g and 450 g, with a cumulative sum of 2250 g for rapeseeds and camelina seeds, respectively. Based on the results obtained, the total mass of oil extracted from rapeseeds was 554.83 g compared to camelina seeds, which produced 559.63 g. The total throughput for rapeseeds was 2.23 kg/h, whereas camelina seeds offered 2.01 kg/h. The oil extraction process of rapeseeds recorded a higher extraction loss of 23.34% in contrast to camelina seeds, which produced 10.70 % extraction loss. In future studies, the present findings will be replicated to confirm the findings established herein. In addition, the effects of other processing factors such as rotational speed, pretreatment temperature and moisture content on oil extraction efficiency and specific energy requirement will be investigated.

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