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Effect of Moisture Content on the Quality and Quantity of Screw-Pressed Flax Seed Oil

Jahongir H. Hasanov[1,*], Sherzod D. Mirzaxmedov[2], Elvira M. Sultonova[1], Shavkat I. Salikhov[1]

[1] *A.S. Sadykov Scientific Institute of Bioorganic Chemistry, Tashkent, Uzbekistan*
[2] *Islam Karimov Tashkent State Technical University, Tashkent, Uzbekistan*

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**Jahongir H. Hasanov: hasanovjahongir1980@gmail.com, https://orcid.org/0000-0003-4095-8734*
Sherzod D. Mirzaxmedov: https://orcid.org/0000-0003-3378-5679
Elvira M. Sultonova: https://orcid.org/0000-0002-9860-6814
Shavkat I. Salikhov: https://orcid.org/0000-0002-7296-1412

Abstract.
Healthy foods and green processing are currently in the focus of scientific attention. Flax is considered a superfood that includes numerous beneficial ingredients. Its oil is a great source of polyunsaturated fatty acids. However, the heat-sensitive futures of the polyunsaturated fatty acids require low-temperature methods. Screw pressing can produce oils at lower temperatures, but a lower oil capacity makes it less advantageous. Pre-treatment of seeds as a crucial pre-processing stage affects the quality and quantity of oil. This research featured the effect of moisture content in flax seeds on the quantity and quality flax seed oil. The study involved local flax (*Linum usitatissimum* L.) from the Qashqadaryo Region, Uzbekistan. Standard methods were used to define the quality parameters of oil, i.e., acid value, free fatty acids content, peroxide value, oil recovery, and sediment content. Regression equations were obtained using the method of regression analysis.

The highest oil recovery of 40.99% was observed at the moisture content of 9.56%. At 7.55%, the oil recovery dropped by 3.17%. The sediment content in the oil increased at lower moisture contents in the flax seeds (14.62–5.55%). The acid value, peroxide value, and free fatty acid content demonstrated both downward and upward trends when the moisture content increased. The moisture content in flax seeds affected the quality and quantity profile of screw-pressed oil. The optimal parameters of oil processing can yield health-beneficial and highly nutritional oil.

Keywords. Screw pressing, moisture content, oil recovery, sediment content, peroxide value, acid value, free fatty acids

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Влияние содержания влаги на качество и количество льняного масла шнекового отжима

Ж. Х. Хасанов[1,*], Ш. Д. Мирзахмедов[2], Э. М. Султонова[1], Ш. И. Салихов[1]

[1] Институт биоорганической химии имени академика А. С. Садыкова, Ташкент, Республика Узбекистан

[2] Ташкентский государственный технический университет им. Ислама Каримова, Ташкент, Республика Узбекистан

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*Ж. Х. Хасанов: hasanovjahongir1980@gmail.com, https://orcid.org/0000-0003-4095-8734
Ш. Д. Мирзахмедов: https://orcid.org/0000-0003-3378-5679
Э. М. Султонова: https://orcid.org/0000-0002-9860-6814
Ш. И. Салихов: https://orcid.org/0000-0002-7296-1412

Аннотация.
В последнее время в центре внимания ученых все чаще оказываются различные аспекты полезного и экологичного питания. Лен относят к категории т. н. суперпродуктов, которые включают в себя множество полезных ингредиентов. Например, льняное масло является отличным источником полиненасыщенных жирных кислот. Однако термочувствительные полиненасыщенные жирные кислоты не терпят термической обработки. Шнековое прессование позволяет производить льняное масло при более низких температурах, но низкий выход продукта делает этот метод невыгодным. Повысить качество масла и увеличить его выход может предварительная обработка семян. Данное исследование было посвящено влиянию содержания влаги в семенах льна на количество и качество льняного масла.
В эксперименте использовали лен (*Linum usitatissimum* L.) из Кашкадарьинской области Узбекистана. Для определения таких параметров, как кислотное число, содержание свободных жирных кислот, перекисное число, выход масла и содержание осадка, использовались стандартные методы. Уравнения регрессии были получены с использованием метода регрессионного анализа.
Наибольший выход масла (40,99 %) наблюдался при влажности 9,56 %. При влажности 7,55 % этот показатель снизился на 3,17 %. Содержание осадка в масле увеличивалось при более низкой влажности семян льна (14,62–5,55 %). При увеличении содержания влаги кислотное число, перекисное число и содержание свободных жирных кислот демонстрировали как тенденцию к снижению, так и к повышению.
Данное исследование показало, что содержание влаги в семенах льна влияет на качественный и количественный профиль масла шнекового отжима. Оптимальные параметры переработки позволяют получить полезное для здоровья и высокопитательное масло.

Ключевые слова. Шнековое прессование, влажность, выход масла, содержание осадка, перекисное число, кислотное число, свободные жирные кислоты

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Introduction

Flax seed (*Linum usitatissimum* L.) oil is a health-beneficial food because it is rich in polyunsaturated fatty acids and other bioactive components [1]. For instance, 40% of oil and fatty acid composition are represented by α-linoleic acid (~ 53%), oleic acid (~ 19%), linoleic acid (~ 17%), palmitic acid (~ 5%), and stearic acid (~ 3%) [2]. In addition, flax seed oil has a favourable n-6/n-3 fatty acids ratio of 0.3:1 [3, 4]. Flax seed oil also contains bioactive plant substances, such as protein, dietary fiber, soluble polysaccharides, lignans, phenolic compounds, vitamins (A, C, F, and E) and minerals (P, Mg, K, Na, Fe, Cu, Mn, and Zn) [5, 6].

Commercial flax seed oil is usually recovered by cold pressing. Higher temperatures fasten extraction and increase the yield but may lead to thermal degradation, especially if the oil is rich in polyunsaturated fatty acids. Moreover, oils with a higher omega-3 content should be processed with extra care at the lowest temperatures possible in order to avoid deterioration and prolong stability [7, 8].

Pressing is the optimal method of oil manufacturing: it is energy-efficient and requires neither expensive equipment nor organic solvents [9]. However, the oil yield is low, and a lot of oil remains in the cake [10, 11]. The oil volume depends on process variables, and by adjusting them, producers can increase the oil volume [12].

Oil recovery can be improved by many ways, e.g., by changing such process parameters as temperature, pressure, screw rate, meal size. Pre-treatments are another option, e.g., dehulling, steaming, size reduction, extrusion, enzymatic hydrolyses, etc. [13].

On the one hand, the abovementioned variables can be changed and developed directly by the engineers and technologists to achieve a particular goal. However, the moisture content in seeds is difficult to control prior to commercial scale operations and storage. Air humidity may accumulate on the seed surface during storage if the original moisture content is lower than the air humidity. If the moisture content in seeds is higher than the air humidity, they may dry during storage. Therefore, the quality of raw material is an important factor that affects oil quality [14].

On the other hand, moisture content in flax seeds may affect the performance of the press and the resulting oil parameters. If the moisture content is low, in may cause increment of oil yield. Higher processing temperatures may cause oxidation and deterioration of oil, which, as a result, cannot be labelled as cold-pressed [15, 16].

Improper conditioning of seeds may increase the temperature of seeds and oil during pressing whereas appropriate conditioning improves the oil removal efficiency [17, 18]. Sediment content is another factor that is very difficult to predict: the results differ depending on the seed type and sometimes even for the same seed type of seed. Sediment content depends on the nature of seeds, initial moisture content, harvesting conditions, storage, seed variety, screw-pressing parameters, etc.

The present research objective was to determine the effect of the moisture content of flax seeds grown in Uzbekistan on the peroxide value, acid value, free fatty acids content (oleic acid), and sediment content of oil.

Study objects and methods

Flax seeds (*Linum usitatissimum* L.) were brought from the Qashqadaryo Region, Uzbekistan. The milling lasted 10 s in a lab scale miller (RRH-350, China). The initial moisture content was determined according to the procedure described in State Standard 10857-64 and State Standard 10856-96.

Moisture content. The samples of flax seeds were weighed using a balance (Scout Pro SPS602F, max weight 600 g, China) and divided into six groups of 0.5 kg each. In the first group of (2×0.5 kg), the moisture content remained at the initial level of 5.55% w.b. The other five seed groups were conditioned by applying equation for the desired moisture content denoted as 2% for each sample [1].

$$x = \frac{M_i (W_f - W_i)}{100 - W_i} \qquad (1)$$

where x is the mass of water to be added; M_i is the initial mass of the sample; W_i is the initial moisture content of the sample in % w.b.; W_f is the final (targeted) moisture content in % w.b.

The calculated amount of distilled water was added into each sample and mixed thoroughly. The conditioned groups were sealed in polyethylene bags. All the samples were stored in a refrigerator at 5°C for 7 days to achieve equilibration with the added water. After that, the samples were kept at room temperature for 2 h. The moisture contents were determined prior to the trials of pilot plant pressing. The real moisture contents were 5.55, 7.55, 9.56, 11.06, 14.62, and 15.57% for future trials. The moisture content determination was triplicated for each sample.

Oil quality parameters. We determined the peroxide value, free fatty acid content, and acid value for each group. Food sector offers no special regulations to evaluate flax seed oil quality parameters, but Codex Alimentarius Commission developed standards for virgin oils and cold-pressed fats and oils [19].

Free fatty acids, peroxide values, and acid values of oil samples were determined according to State Standard 31933-212 and State Standard 27107-2016. All quality tests were repeated five times.

Screw pressing. We used a screw press (Nsh-150, 1214 HII, Tashkent, Uzbekistan) that can be applied to sunflower seeds, soy beans, and flax seeds. Its capacity was 15–75 kg/h, the main electromotor power was 16 kw, and the residual oil of the cake was 9–12%. The interior diameter of the screw shaft was 140 ± 4 mm, while the distance between oil outlet holes equalled 0.12 ± 0.02 mm. The press cake discharging place could be adjusted between 10.3 and 26.3 mm (Fig. 1).

The experiments were performed as described below. The flax seed samples were fed to the hopper. The samples (0.5 kg) were processed by the following moisture content: 5.55, 7.55, 9.56, 11.06, 14.62, and 15.57%. The trials were conducted at constant parameters: the frequency was 15 Hz, the distance to the meal outlet was 1.25 mm.

We used 1 kg of seeds to adapt the screw press to the working conditions. The experiments lasted 15~25 min. After that, the flow of the cake and oil was stopped at the exit of the press, and the next trial started. The experiments were carried out in duplicate, and the oil with its sediments was gathered in a glass container.

Sediment content in oil. The sediment was separated from residues via centrifugation (Tslmn-P10-01-Elekon,

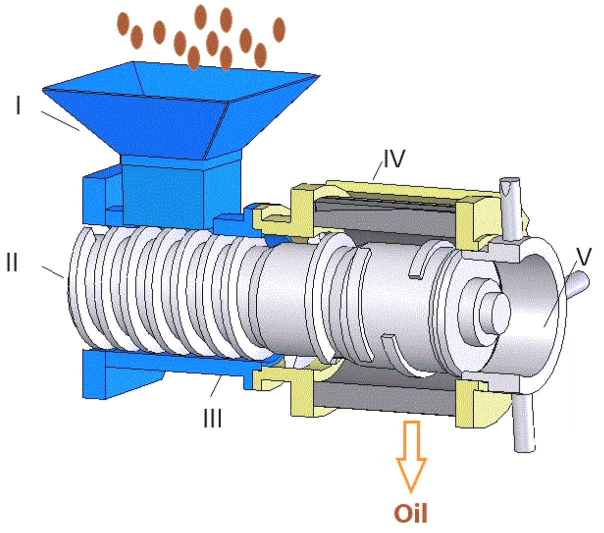

Figure 1. Screw press flow chart: I – fed hopper, II – screw, III – press cylinder, IV – outlet holes, V – meal outlet

Рисунок 1. Схема шнекового пресса: I – загрузочная воронка, II – шнек, III – цилиндр пресса, IV – выходные отверстия, V – выход шрота

Russia); the solid phase was washed with chloroform and separated using a vacuum filter. The sediment was dried and weighed. The sediment was dried and weighed. Its content in oil was determined by calculating the ratio between sediment content and recovered oil.

Oil recovery calculation. The oil recovery (OR, %) were calculated as the ratio of extracted oil to the initial amount of oil in the seeds:

$$OR = \left(1 - \frac{Wm \times Com}{Wrm \times Corm}\right) \times 100$$

where *Wm* is the weight of meal; *Com* is the content of oil in meal; *Wrm* is the weight of raw material; *Corm* is the content of oil in raw material.

Results and discussion

Oil recovery and sediment content. By increasing the moisture content of the flax seeds, we affected the oil recovery directly. For several moisture contents, a variation of oil recovery was observed during flax seed pressing. When the moisture content reached 5.55~9.56% w.b., the oil recovery increased from 24.89 to 40.99% (Fig. 2a). However, the group with 11.05% w.b. moisture content caused plugging in the screw press. Some cake came from the outlet of the press and stopped it, thus increasing the temperature of the head of the press. The pressing was stopped and continued only after the temperature of the head decreased. No plugging problem was observed for other moisture contents. Yun *et al.* faced the same plugging problem at the beginning of the pressing, but in our case, it occurred in the middle of the moisture contents (11.05%), which may be due to the high temperature of the head [20]. However, other studies showed that this issue appeared in the lower moisture contents. The highest oil recovery was registered when the moisture content of dehulled flax seeds was below 6% [21]. However, a higher moisture content does not neccesserily lead to plugging.

When the moisture content of seeds was 11.05–15.57% w.b., the oil recovery decreased moderately from 13.17 to 4.34% (Fig. 2a). The general trend of our study was that we achieved a greater flax seed oil recovery at a lower moisture content while a higher initial moisture content was responsible for a lower oil yield. Probably, the high moisture contents and humidity in the raw material had a lubricating effect and reduced the friction inside the press. Moreover, wet seeds had a greater plasticity, which might also decrease the pressure inside the press. Other studies report that the friction grew stronger inside the barrel when the moisture content decreased [22, 23]. Perhaps, the friction resistance caused high temperatures inside the barrel. As a result, the oil viscosity decreased inside the seed pores, and the oil could move easier through them.

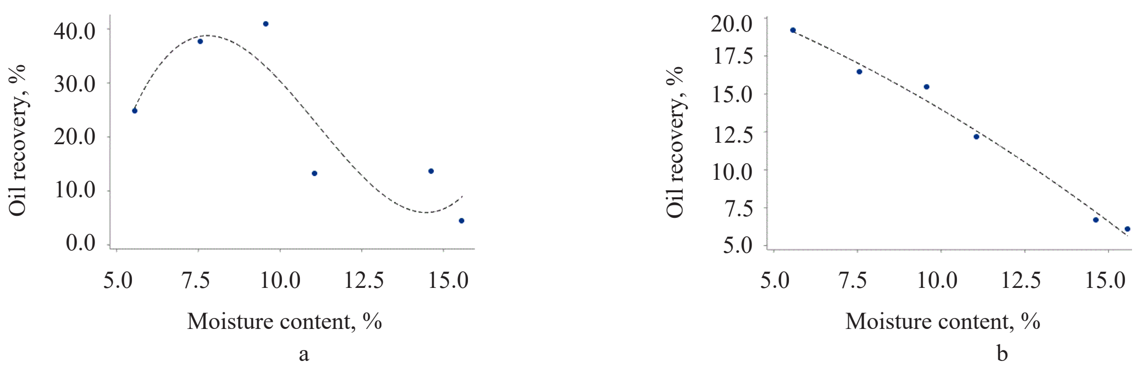

Figure 2. Impact of moisture content of flax seeds on oil recovery (a) and sediment content in oil (b)

Рисунок 2. Влияние влажности семян льна на выход масла (a) и содержание осадка (b)

The general trend we detected in our experiments was in line with the previous studies. The highest oil percentage was recovered at 9.56% moisture content; the oil recovery decreased as the moisture content reached 9.56% w.b. Mridula *et al.* obtained the best oil recovery (82.91%) at 6.4% moisture content [21]. Singh *et al.* reported that the flax seed moisture content fell from 13.8 to 6.5% w.b. whereas the oil recovery showed inverse results [22]. Yun *et al.* managed to enhance their oil recovery (70.1–80.57%) when they reduced the moisture content from 11.06 to 6.1% w.b. respectively at the 6-mm choke size [20]. The data for oil recovery were different because they depended on the capacity of the screw press, distribution of moisture among the seeds, the seed type, etc. Also, the cake obtained at the highest moisture content looked more customer-appealing than the samples obtained at the lowest moisture content.

The sediment content in oil increased significantly from 6.07 to 19.2% when the moisture content decreased from 15.57 to 5.55% (Fig. 2b). Our results for the sediment content were higher compared to other studies. The difference might have been caused by the frictional resistance. Mridula *et al.* observed the highest sediment content when the moisture content in the seeds was 6.4% [21]. However, when Singh *et al.* increased the moisture content of the flax seeds from 6.5 to 13.8%, the sediment content in oil did not change significantly [22].

The quality of oil depends on many factors, such as genotype, harvesting, geography, storage, and processing. Other studies applied no special standard for flax seed oil quality to evaluate cold-pressed oils (Australia New Zealand Food Standards Code. Standard 2.4.1. Edible oils and New Zealand Food Regulation. General standard for edible fats and edible oils) [19].

Table 1 summarizes the effect of moisture contents in the flax seeds on the quality parameters of oil, e.g., acid value, peroxide value, and free fatty acids. The acid value demonstrated a downward trend 2.65~1.47 mg KOH/g as the moisture content increased from 5.55 to 11.05% w.b. However, acid values increment (1.79 and 1.905 mg KOH/g) occurred at the moisture contents of 14.62 and 15.57% w.b., respectively. According to the standard for edible fats and oils, the highest limit of acid value is 4.0 mg KOH/g [19]. Our results did not exceed the recommended limit. The acid values decreased faster when the moisture content reached 11.05% and increased together with the moisture content. The content of free fatty acids (oleic, %) declined from 1.33 to 0.74% when the moisture content was below 11.05% w.b. The maximal content of free fatty acids in oil never exceeded 2%. However, the presence of free fatty acids in oils is known to be an indicator of oil degradation, and their content depends on time, temperature, and moisture [23]. In our study, the free fatty acids followed the same pattern as the acid value.

The acid value increased from 21.59 to 24.39 mg KOH/g when the moisture content was 6.3–13.2% but declined at 16.6% moisture content. In a study that featured neem seeds, Adejumo *et al.* reported that the free fatty acid content also demonstrated upward and downward behaviour depending on the moisture content in the seeds [25]. In the same study, the acid value and the free fatty acid content decreased when the moisture content fell below 15% and then stabilized. However, the below-mentioned studies reported that a higher moisture content increased the contents of acid value and free fatty acids. For instance, when the moisture content of the seeds increased from 5 to 10%, the acid value of the unroasted rapeseed cold-pressed oil increased slightly [13]. When Rokosik *et al.* increased the moisture content during 14 days of storage, the acid value of the cold-pressed canola oil increased as well [26].

The peroxide value of oil is an empirical expression of oxidation which develops early during lipid oxidation. Like other quality aspects of the oil, the peroxide value decreased when the moisture content increased. The highest peroxide value was 4.25 mEq/kg at 5.55% w.b moisture content, and the lowest peroxide value of 1.62 mEq/kg was detected at 14.62% w.b. moisture content. However, the peroxide value increased a little when the moisture content was at its highest (15.57% w.b.) (Table 1). For all moisture contents in this study, the peroxide value remained within the maximal limit for cold-pressed oil in Codex Alimentarius [19]. Adejumo *et al.* bserved the same decrease trend in the peroxide value for neem oil when the moisture content was above 10% [25]. However, other studies reported an increase in the peroxide value of oil caused by increasing the moisture content in unroasted canola seeds [19, 26].

Table 1. Effect of moisture content on oil quality properties

Таблица 1. Влияние содержания влаги на показатели качества масла

Oil properties \ Moisture content, %	5.55 w.b.	7.55 w.b.	9.56 w.b.	11.05 w.b.	14.62 w.b.	15.57 w.b.	Recommendations
Acid value, mg KOH/g	2.65 ± 0.28	2.20 ± 0.74	1.79 ± 0.22	1.47 ± 0.23	1.79 ± 0.15	1.905 ± 0.110	4*
Free fatty acids (oleic, %)	1.33 ± 0.19	1.10 ± 0.11	0.90 ± 0.09	0.74 ± 0.05	0.900 ± 0.175	0.957 ± 0.140	< 2**
Peroxide value, mEq/kg	4.20 ± 0.42	4.00 ± 0.38	2.34 ± 0.15	2.10 ± 0.22	1.62 ± 0.11	1.66 ± 0.11	15*

* Codex Alimentarius Commission [19];

** G. Nagaraj [24].

Table 2. Regression equations for oil recovery, sediment content, acid value, free fatty acids, and peroxide value

Таблица 2. Уравнения регрессии для нефтеотдачи, осадка, кислотного числа, свободных жирных кислот и перекисного числа

Quality and quantity characteristics	Models	Numbers of models	R^2
Oil recovery, %	$–199.1 + 74.4\ MC_{(wb)} – 7.3MC_{(wb)}{}^2 + 0.2MC^3{}_{(wb)}$	(1)	77.80
Sediment content, %	$23.66–0.6\ MC_{(wb)} – 0.03MC^2{}_{(wb)}$	(2)	98.81
Acid value, mg KOH/g	$5.4–0.6\ MC_{(wb)} + 0.02MC^2{}_{(wb)}$	(3)	96.28
Free fatty acids (oleic, %)	$2.7–0.3\ MC_{(wb)} + 0.01MC^2{}_{(wb)}$	(4)	96.46
Peroxide value, mEq/kg	$8.6–0.9\ MC_{(wb)} + 0.021MC^2{}_{(wb)}$	(5)	93.27

MC – moisture content.

MC – содержание влаги.

The coefficient of determination R^2 means the degree of the fitness of regression model to the data observed. Table 2 shows that Model 1 demonstrated a lower coefficient of determination (R) with 77.8%. In this particular case, R was 77.8% of variance of oil recovery, that corresponded to the moisture content share. In term of sediment content, the coefficient of determination was high enough with 98.81%. Perhaps, the sediment content depended more on the moisture content in the flaxseed than Model 1. Also, Model 3 demonstrated high R value (96.28%) for the acid value. The model of free fatty acids and moisture content relationship had a similar R value of 96.46%. The coefficient of determination for the peroxide value was 93.27%. Overall, the models demonstrated a substantial ability to fit the experimental data. Perhaps, the remaining part of determination coefficients were due to the other influencing factors that were not taken in account in our case (Table 2).

Conclusion

The moisture content of flax seeds affected the quality and quantity of oil. The oil recovery increased when the moisture content decreased. By establishing a suitable moisture content of the flax seeds, producers can achieve the pre-planned goals of production in terms of oil quality and quantity.

Contribution

All the authors equally took part in the research and are equally responsible for any potential plagiarism.

Conflict of interest

The authors declare no conflict of interests regarding the publication of this article.

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References/Список литературы

1. Teh S-S, Morlock GE. Effect-directed analysis of cold-pressed hemp, flax and canola seed oils by planar chromatography linked with (bio)assays and mass spectrometry. Food Chemistry. 2015;187:460–468. https://doi.org/10.1016/j.foodchem.2015.04.043

2. Dzuvor CKO, Taylor JT, Acquah C, Pan S, Agyei D. Bioprocessing of functional ingredients from flaxseed. Molecules. 2018;23(10). https://doi.org/10.3390/molecules23102444

3. Grajzer M, Szmalcel K, Kuźmiński Ł, Witkowski M, Kulma A, Prescha A. Characteristics and antioxidant potential of cold-pressed oils – Possible strategies to improve oil stability. Foods. 2020;9(11). https://doi.org/10.3390/foods9111630

4. Hasanov J, Navro’zov S. Extraction of seed oils with rich soaress of fatty asids. Proceedings of Sceitific Conference of PhD Studends of FAFR, FBFS and FHLESUA; 2019; Nitra: Slovak University of Agriculture in Nitra; 2019. p.75.

5. Jheimbach LLC, Port Royal VA. Determination of the GRAS status of the addition of whole and milled flax seed to conventional foods and meat and poultry products [Internet]. [cited 2022 Jun 20]. Available from: https://wayback.archive-it.org/7993/20170607013434%20/https://www.fda.gov/downloads/Food/IngredientsPackagingLabeling/GRAS/NoticeInventory/UCM269248.pdf

6. Al-Hassawi F, Al-Ghanim J, Al-Foudari M, Al-Othman A, Sidhu JS. Effects of flaxseed on the nutritional and sensory qualities of pan and Arabic flat breads. Foods and Raw Materials. 2023;11(2):272–281. https://doi.org/10.21603/2308-4057-2023-2-571

7. Grajzer M, Wiatrak B, Gębarowski T, Matkowski A, Grajeta H, Rój E, *et al.* Chemistry, oxidative stability and bioactivity of oil extracted from *Rosa rugosa* (Thunb.) seeds by supercritical carbon dioxide. Food Chemistry. 2021;335. https://doi.org/10.1016/j.foodchem.2020.127649

8. Sydow Z, Idaszewska N, Janeba-Bartoszewicz E, Bieńczak K. The influence of pressing temperature and storage conditions on the quality of the linseed oil obtained from *Linum Usitatissimum* L. Journal of Natural Fibers. 2021;18(3):442–451. https://doi.org/10.1080/15440478.2019.16288667

9. Bhargavi G, Nageswara Rao P, Renganathan S. Review on the extraction methods of crude oil from all generation biofuels in last few decades. IOP Conference Series: Materials Science and Engineering. 2018;330. https://doi.org/10.1088/1757-899X/330/1/012024

10. Shim YY, Gui B, Wang Y, Reaney MJT. Flaxseed (*Linum usitatissimum* L.) oil processing and selected products. Trends in Food Science and Technology. 2015;43(2):162–177. https://doi.org/10.1016/j.tifs.2015.03.001

11. Willems P, Kuipers NJM, De Haan AB. Hydraulic pressing of oilseeds: Experimental determination and modeling of yield and processing rates. Journal of Food Engineering. 2008;89(1):8–16. https://doi.org/10.1016/j.jfoodeng.2008.03.023

12. Kalogianni EP, Georgiou D, Hasanov JH. Olive oil processing: Current knowledge, literature gaps, and future perspectives. Journal of the American Oil Chemists' Society. 2019;96(5):481–507. https://doi.org/10.1002/aocs.12207

13. Jahongir HH, Sherzod DM, Shavkat IS. Screw pressed (*Linum usitatissimum*) oil. Book of Abstracts of the 5th International Scientific Conference Agrobiodiversity for Improving the Nutrition, Health, Quality of Life and Spiritual Human Development; 2021; Nitra. Nitra: Slovak University of Agriculture; 2021. p. 59. https://doi.org/10.15414/2021.9788055224015

14. Siger A, Józefiak M, Górnaś P. Cold-pressed and hot-pressed rapeseed oil: The effects of roasting and seed moisture on the antioxidant activity, canolol, and tocopherol level. Acta Scientiarum Polonorum, Technologia Alimentaria. 2017;16(1):69–81. https://doi.org/10.17306/J.AFS.2017.2017.0458

15. Singh J, Bargale PC. Development of a small capacity double stage compression screw press for oil expression. Journal of Food Engineering. 2000;43(2):75–82. https://doi.org/10.1016/S0260-8774(99)00134-X

16. Wiesenborn D, Doddapneni R, Tostenson K, Kangas N. Cooking indices to predict screw performance for crambe seed. Journal of the American Oil Chemists' Society. 2001;78(5):467–471. https://doi.org/10.1007/s11746-001-0287-y

17. Shim YY, Gui B, Wang Y, Reaney MJT. Flaxseed (*Linum usitatissimum* L.) oil processing and selected products. Trends in Food Science and Technology. 2015;43(2):162–177. https://doi.org/10.1016/j.tifs.2015.03.001

18. Oilseed processing for small-scale producers [Internet]. [cited 2022 Jun 20]. Available from: https://www.kpu.ca/sites/default/files/Oilseed%20Processing%20for%20Small-Scale%20Producers%20.pdf

19. Codex Alimentarius. Codex Standard for edible fats and oils not covered by individual standards [Internet]. [cited 2022 Jun 20]. Available from: https://www.fao.org/3/y2774e/y2774e03.htm#bm3

20. Zheng Y, Wiesenborn DP, Tostenson K, Kangas N. Screw pressing of whole and dehulled flaxseed for organic oil. Journal of the American Oil Chemists' Society. 2003;80(10):1039–1045. https://doi.org/10.1007/s11746-003-0817-7

21. Mridula D, Barnwal P, Singh KK. Screw pressing performance of whole and dehulled flaxseed and some physico-chemical characteristics of flaxseed oil. Journal of Food Science and Technology. 2013;52(3):1498–1506. https://doi.org/10.1007/s13197-013-1132-6

22. Singh KK, Jhamb SA, Kumar R. Effect of pre-treatments on performance of screw pressing for flaxseed. Journal of Food Process Engineering. 2011;35(4):543–556. https://doi.org/10.1111/j.1745-4530.2010.00606.x

23. Mahesar SA, Sherazi STH, Khaskheli AR, Kandhroc AA, Unddin S. Analytical approaches for the assessment of free fatty acids in oil and fat. Analytical Methods. 2014;14(6):4956–4963. https://doi.org/10.1039/C4AY00344F

24. Nagaraj G. Oilseeds – Properties, processing, products and procedures. New Delhi: New India Publishing Agency; 2009. 602 p.

25. Adejumo BA, Inaede SG, Adamu TS. Effect of moisture content on the yield and characteristics of oil from *Moringa oleifera* seeds. Academic Research International. 2013;4(4):160–170.

26. Rokosik E, Dwiecki K, Siger A. The quality of cold-pressed rapeseed oil obtained from seeds of *Brassica napus* L. with increased moisture content. Acta Scientiarum Polonorum, Technologia Alimentaria. 2019;18(2):205–218. https://doi.org/10.17306/J.AFS.2019.0672

27. Singh KK, Wiesenborn DP, Tostenson K, Kangas N. Influence of moisture content and cooking on screw pressing of crambe seed. Journal of the American Oil Chemists' Society. 2002;79(2):165–170. https://doi.org/10.1007/s11746-002-0452-3

28. Singh J, Bargale PC. Mechanical expression of oil from linseed. Journal of Oilseeds Research. 1990;7:106–110.