POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 25(1): 106–113, Y. 2010

DOI 10.2478/v10020-010-0008-8

PHYSICOCHEMICAL CHARACTERISTICS OF LINSEED OIL AND FLOUR

Beata Piłat, Ryszard Zadernowski

Chair of Food Plant Chemistry and Processing
University of Warmia and Mazury in Olsztyn

K e y w o r d s: linseed oil, flour, chemical composition, fatty acids, dietary fiber composition, dietary fiber forms.

A b s t r a c t

The objective of the study was to determine the chemical composition of a new linseed cultivar Złocisty, characterized by a light seed coat. In this study, determinations were conducted for contents of: water and volatile substances, protein, fat, dietary fiber, acid detergent fiber (ADF) and neutral detergent fiber (NDF), pectins, starch, saccharides, methyl esters of fatty acids, peroxide number of fat, acidic and iodine values of fat, as well as for the percentage contribution of particular forms of lipids, sterols and tocopherols.

An analysis of the chemical composition of linseed oil and flour demonstrated that both of these products may be valuable components of dietary supplements. The chemical composition of linseed oil was determined with special attention paid to bioactive substances from tocopherols, sterols and phospholipids. Based on the assayed chemical composition of flour, it appears that it might constitute a rich source of dietary fiber and zinc. The management of both of these semi-products affords the possibility of waste-free seed processing.

CHARAKTERYSTYKA FIZYKOCHEMICZNA OLEJU I MĄKI LNIANEJ

Beata Piłat, Ryszard Zadernowski

Katedra Przetwórstwa i Chemii Surowców Roślinnych
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: olej lniany, mąka, skład chemiczny, kwasy tłuszczowe, skład błonnika, formy błonnika.

Address: Beata Piłat, University of Warmia and Mazury, pl. Cieszyński 1, 10-957 Olsztyn, Poland, phone: +48 (089) 523 36 19, e-mail: pilatowa@o2.pl

A b s t r a k t

Celem pracy jest ocena składu chemicznego nasion lnu nowej odmiany Złocisty o jasnej okrywie nasiennej. W trakcie badań oznaczono ilość: wody i substancji lotnych, białka, tłuszczu, błonnika pokarmowego, błonnika detergentowego kwaśnego (ADF) i obojętnego (PDF), pektyn, skrobi, cukrów, estrów metylowych kwasów tłuszczowych, liczbę nadtlenkową, kwasową i jodową tłuszczu, a ponadto oznaczono udział poszczególnych form lipidów, sterole i tokoferole.

Przedstawione w pracy wyniki składu chemicznego oleju i mąki lnianej wskazują, że oba te produkty mogą być wartościowym komponentem preparatów z grupy suplementów diety. Oznaczono skład chemiczny oleju, ze szczególnym zwróceniem uwagi na substancje biologicznie aktywne z grupy tokoferoli i steroli oraz fosfolipidów. Na podstawie składu chemicznego mąki ustalono, że może ona stanowić bogate źródło błonnika pokarmowego i cynku. Zagospodarowanie obu tych półproduktów stwarza możliwość bezodpadowego przerobu nasion.

Introduction

Vegetable and animal fats are one of the major constituents of food. In the past, attention was mainly paid to their energetic value, while their health-promoting and even therapeutic values remained underestimated. At that time, it was not known that fats were a valuable source of biologically-active substances. Owing to the various possibilities of man to access sources of edible fats in different climatic zones, the contribution of vegetable and animals fats in the everyday diet of particular societies was, and still is, diversified. The basic fat of the Arctic population is the fat of fish and marine animals, whereas in the case of the steppe population – animal fats (lard, suet), in the case of the population inhabiting the moderate climatic zone – plant and animal fats (with prevailing intake of vegetable fats), and in the case of the population of the equatorial zone – oils of tropical plants. In turn, the Southern-European, Mediterranean cuisine has been predominated by vegetable fats obtained, most of all, from olive trees. The cuisine of the Central Europe, including the Polish diet, was mainly based on animal fats (lard, butter) and occasionally – in the period of Lent – also on vegetable oils produced from seeds of hemp, flax, linseed, and sunflower. The oils were obtained as a result of pressing earlier heated seeds on various pressing devices (expellers, hydraulic presses). The current state of the art in this respect indicates that the process of heating up or roasting seeds destroys most of the biologically-active substances in oil seeds, with vitamins and sterol being particularly degraded. In the twentieth century, even though the role of vitamins in nutrition was explicitly identified, the oil industry did not introduce any new production technologies. Drastic conditions of roasting seeds before their pressing were still in use. It was not until the end of the last century that cold-pressed oils, including linseed oil, achieved widespread recognition. Cold-pressed oil constitutes a rich source of essential fatty acids (EFA). They serve a number of important nutritional functions in the human body although, paradoxically, they are not synthesized therein and thus must be delivered with food (PASIOWIEC-ŻUREK 2005). A number of authors claim that a deficiency of EFAs may be a causative agent of various diseases, because they participate in the synthesis of hormones regulating different vital and immune processes (KRYGIER 1997). Especially high quantities of unsaturated fatty acids are utilized by the brain and the nervous system. These acids are also a constituent of cellular membranes and determine the availability of fat-soluble vitamins (A, D, E, K). The first scientist to identify the beneficial properties of linseed oils was a doctor of biological and natural sciences – Joanna Budwig (1909–2003). She was the first to introduce linseed oil to a patient's diet.

Flour remaining after the process of seed pressing is also a valuable curative component. In Poland, it has been applied in the treatment of digestive tract diseases and as a wound-healing agent.

Over the years, flax – as an industrial plant providing a valuable oil and fibers for textiles – has undergone a number of breeding modifications involving its fatty acid composition, fiber content and seed coat color. To date, most studies have addressed the seeds of traditional cultivars, characterized by a dark seed coat, whereas few publications have been devoted to seeds of a new cultivar with a light, golden seed coat. For this reason, the objective of the present study was the chemical characteristics of linseeds of the Złocisty cultivar, characterized by a yellow seed coat.

Material and Methods

The object of the study was cold-press linseed oil and linseed flour remaining after the pressing process. These semi-products were obtained upon pressing linseeds of Złocisty cultivar with a light seed coat. The seeds were purchased in 2008 and were pressed on a Komet type expeller (Germany). The temperature of the pressing head did not exceed 40°C. The resultant oil was purified by centrifugation in an MPW340.ik type centrifuge, whereas the pomace was ground in a laboratory mill TECATOR and standardized by sieving through a screen with a 0.25 mm mesh diameter.

Analytical methods: The refraction index and density were determined with the method described by KREŁOWSKA-KUŁAS (1993). The content of water and volatile substances was assayed according to the Polish Standard (*Oleje i tłuszcze...* PN-EN ISO 662), whereas protein content was determined according to Kjeldahl's method (KLEPACKA 2000), fat content – acc. to the Polish Standard (*Oznaczanie zawartości tłuszczu...* PN-73/R-66164), dietary fiber content – acc. to the Polish Standard (*Oznaczanie zawartości błonnika pokar-*

mowego... PN-A-79011-15:1998), acidic dietary fiber (ADF) content – acc. to AOAC Standard (*Official methods...* 1990), content of pectins following the method of Morris (PIJANOWSKI 1973), content of starch in a solution of hydrochloric acid – with the polarimetric method (*Official methods...* 1975), content of saccharides – acc. to the Polish Standard (*Przetwory owocowe...* PN-90/A-75101/07) and content of methyl esters of fatty acids – with the method of gas chromatography acc. to the Polish Standard (*Analiza estrów...* PN-EN ISO 5508). The peroxide number was determined according to the Polish Standard (*Tłuszcze roślinne...* PN-ISO 3960), the acidic value – acc. to the Polish Standard (*Tłuszcze roślinne...* PN-74/R-66165), whereas the iodine value – following the method of Hanuš (KREŁOWSKA-KUŁAS 1993). The content of particular lipid fractions was assayed acc. to the Polish Standard (*Produkty przetwarzania...* PN-EN 14105:2004), content of sterols – acc. to the Polish Standard (*Oleje...* PN-EN ISO 12228), and content of tocopherols – acc. to the Polish Standard (*Artykuły żywnościowe...* PN-EN 12822). The concentrations of zinc and selenium were determined using the method of WHITESIDE and MINER (1984).

Results and Discussion

Natural fats extracted from different oil seeds, including linseeds, are a multi-component mixture of various lipids, with triacylglycerols being the major constituent. All other lipids contained in natural lipids are commonly referred to as concomitant substances (phospholipids, glycolipids, sterols, fat-soluble vitamins, carbohydrates). The percentage contribution of individual components is not a constant value and is determined by a variety of factors, including: seed maturity, fat extraction method, method and time of storage. The percentage composition of cold-pressed linseed oil is provided in Table 1. And so, in the cold-pressed linseed oil examined, the concentration of triacylglycerols accounted for 97±1.5%, that of partial acylglycerols (di- and monoglycerols) for 1.5±0.5% and that of polar phospholipids – for 0.5±0.1%. The contents of other components (tocopherols, free fatty acids, sterols and carbohydrates) did not exceed 1.0%. The refraction index is a typical trait of fats and oils. In linseed oil produced from seeds of traditional cultivars it accounts for 1.480 (AMOO et al. 2006), which is slightly higher than that determined in the linseed oil examined in the current study, *i.e.* 1.477 (Table 2). The value of the acidic level determines the quantity of free fatty acids. In the case of oils, this value is not constant either, as it results from the hydrolysis process. In the linseed oil examined, the value of the acidic level did not exceed values stipulated in the Polish Standard (*Tłuszcze roślinne...*

PN-A-869006/A1). Likewise, the peroxide level – which is a measure of fat rancidity – did not exceed values determined in the Polish Standard (Table 2). In turn, the iodine number, which is a measure of unsaturated fatty acid content of fat, was determined in the analyzed fat at a level of 139.53 g I_2/100 g. In linseed oils produced from seeds of traditional cultivars, the value of this parameter accounted for 178 g I_2/100 g.

Table 1
Composition (%) of linseed oil produced by cold-pressing of seeds

Specification	Content
Triacylglycerols	96.0±1.5
Partial acylglycerols + free fatty acids	1.5±0.5
Polar lipids	1.5±0.6
Other constituents	1.0±0.2
Sterols (mg/100 g)	250
Tocopherols (mg/100 g)	37.4

Table 2
Selected physicochemical parameters of linseed oil produced by cold-pressing of seeds

Parameters	Oil
Density (kg dm^{-3})	0.927
Refractive index (20°C)	1.477
Content of water and volatile substances (%)	0.084
Acidic value (mg KOH g^{-1})	0.88
Iodine value (g I_2/100g)	139.53
Peroxide number (meq O_2 kg^{-1})	0.34

The fatty acid composition of linseed oil and fat remaining in the flour is presented in Table 3. Linseed oil is a rich source of polyunsaturated fatty acids, including primarily: linolic acid and α-linolenic acid belonging to omega-3 fatty acids (Table 3). The percentage contribution of both these acids reached around 73%. A negligibly higher content of α-linolenic acid was determined in fat remaining in the flour, which may be due to the fact that during cold--pressing a higher quantity of polar fat (richer in polyunsaturated fatty acids) remains in the linseed flour. The third fatty acid, in terms of content, is oleic acid whose content in oil reached 17.3% and in flour fat – 14.3%. In comparing the results obtained with literature data, a conclusion may be drawn that the genetic modification that had led to a change in the color of seed coat, did not evoke any significant changes in fatty acids composition (BERGLUND 2002).

Table 3
Content of fatty acids (%) in linseed oil and flour fat

Fatty acid	Content of fatty acid in:	
	oil	fluor fat
Myristic ($C_{14:0}$)	0.10	0.05
Palmitic ($C_{16:0}$)	5.03	8.17
Palmitoleic ($C_{16:1}$)	0.10	0.06
Margaric ($C_{17:0}$)	0.10	0.10
Stearic ($C_{18:0}$)	4.01	2.02
Oleic ($C_{18:1}$)	17.33	14.31
Octadecanoic ($C_{18:1}$)	0.60	0.50
Linolic ($C_{18:2}$)	22.73	21.62
α-linolenic ($C_{18:3}$)	50.00	53.17

Table 4
Selected constituents of linseed flour

Constituents	Content (g/100 g f.w.)
Pectin	17.5
Fat	9.9
Saccharides	3.0
Protein	37.4
Starch	7.7
Total dietary fiber	63.3
Soluble dietary fiber	11.9
Insoluble dietary fiber	51.4
NDF*	38.1
ADF*	27.2
Cellulose	17.8
Hemicellulose	10.9
Lignins	9.4
Zinc (mg/100 g)	13.27
Selenium (μg/100 g)	0.6

*NDF – NEUTRAL DETERGENT FIBER
*ADF – ACIDIC DETERGENT FIBER

Linseed oil is a rich source of tocopherols and sterols. In the oil tested the content of tocopherols accounted for 37.4 mg/100 g and of sterols – for 250 mg/100 g. The results obtained in our study correspond with findings of BARTKOWIAK-FLUDRA et al. (2006) (tocopherols). In turn, linseed flour may be a valuable component of dietary supplements. It contains considerable quantities of dietary fiber, including pectins and protein. In addition, it is a rich source of zinc. Contents of starch and saccharides reached ca. 10%, whereas the content of fat remaining after the pressing process accounted for 9.9% (Table 4).

Dietary fiber occurs in all products of plant origin. The notion of dietary fibers describes organic compounds of cellular membranes and supportive tissues of plants that remained after the removal of proteins, fats and carbohydrates. They are resistant to hydrolysis with digestive enzymes in the gastrointestinal tract of man (DIOWKSZ 2006). In the reported study, the content of dietary fiber (crude fiber) in linseed flour was shown to reach 63.3%. Methods based on acidic and base-acidic hydrolysis make the determination of selected fractions of dietary fiber impossible, duet to losses resulting from the use of concentrated acids or lyes. For this reason, fractions of dietary fiber non-digestible in the gastrointestinal tract are often determined by means of detergent methods. In laboratory practice, use is made of various combinations of detergents and media, which enables obtaining two type of dietary fiber. The application of a detergent in a neutral medium enables determining the neutral detergent residue, i.e. the content of cellular membranes of plants in the material examined, whereas the use of a detergent in an acidic medium enables assaying the acidic detergent fiber (ADF), which corresponds to the contents of lignin and cellulose. In the material analyzed in our study, the content of neutral detergent fiber (NDF) accounted for 38.1% and was higher by ca. 10% than that of the acidic detergent fiber (Table 4). Apart from the total fiber content and detergent fiber content, we have also determined the so-called dietary fiber, which constitutes residues of cell walls resistant to enzymatic hydrolysis in the gastrointestinal tract of man. Dietary fiber is not a homogenous substance and thus it includes compounds that are soluble in water (pectins, gums, mucilages) and those that are insoluble in water (cellulose, hemicellulose, lignins, resistant starch). In the linseed flour examined, the insoluble dietary fiber was found to prevail and its content was ca. 5 times higher than that of the soluble dietary fiber. The content of pectins – that constitute the water-soluble dietary fiber – was determined at a level of 17.5 g/100 g flour. The contribution of the selected components of the insoluble dietary fiber fractions, including: cellulose, hemicellulose and lignins, accounted for 37.1 g/100 g flour.

Conclusions

The results presented in respect of the chemical composition of oil and flour obtained from linseed of Złocisty cultivar indicate that both these products may be a valuable component of preparations from a group of dietary supplements. The chemical composition of oil was confirmed with special emphasis put on its bioactive substances belonging to groups of tocopherols, sterols and phospholipids. In turn, linseed flour remaining after the pressing process may serve as a rich source of dietary fiber and zinc. The management of both these semi-products affords the possibility of waste-free processing of linseeds.

Translated by JOANNA MOLGA, JOANNA JENSEN, MARK JENSEN

Accepted for print 17.12.2009

References

AMOO I.A., ADEBAYO O.T., OYELEYE A.O, OYELEYE A.O. 2006. *Chemical evaluation of winged beans (Psophocarpus tetragonolobus), pitanga cherries (Eugenia uniflora) and orchid fruit (Orchid fruit mystica).* African Jurnal of Food Agriculture Nutrition and Development. 6(2): 1–12

Analiza estrów metylowych kwasów tłuszczowych metodą chromatografii gazowej. PN-EN ISO 5508.

Artykuły żywnościowe. Oznaczenie zawartości witaminy E metodą wysokosprawnej chromatografii cieczawej. Pomiar alfa-, beta-, gamma- i delta-tokoferoli. PN-EN 12822.

BARTKOWIAK-FLUDRA E., JASIŃSKA-STEPNIAK A, GOGOLEWSKI M., DELBOWSKI B., 2006. *Zmiany siły redukującej i zdolności wygaszania wolnych rodników w wybranych olejach tłoczonych na zimno w czasie ich przechowywania.* Bromat. Chem. Toksykol., XXXIX (2): 127–133.

BERGLUND D.R., 2002. *Flax: new uses and demands, Trends in new crops and new uses.* ASHS Press 358–360.

DIOWKSZ A. 2006. *Błonnik pokarmowy-wielofunkcyjny kompleks składników.* Przegląd Piekarski i Cukierniczy, 9: 16–20.

KLEPACKA M. 2000. *Analiza żywności,* część pierwsza. Fundacja Rozwój SGGW, Warszawa.

KREŁOWSKA-KUŁAS M. 1993. *Badanie jakości produktów spożywczych.* PWE Warszawa, 70–74.

KRYGIER K. 1997. *Współczesne roślinne tłuszcze jadalne.* Przemysł Spożywczy, 4: 11–13.

Official Metods of Analysis AOAC. AOAC, Washington, D.C, 1990, 1975.

Oleje tłuszcze roślinne oraz zwierzęce. Oznaczanie poszczególnych steroli i ich całkowitej zawartości. Metoda chromatografii gazowej. PN-EN ISO 12228.

Oleje i tłuszcze roślinne oraz zwierzęce – Oznaczanie zawartości tokoferoli i tokotrienoli wysokosprawna chromatografia cieczowa. PN-EN ISO 9936/2006.

Oleje i tłuszcze roślinne oraz zwierzęce. Oznaczanie zawartości wody i substancji lotnych. PN-EN ISO 662.

Oznaczanie zawartości błonnika pokarmowego. PN-A-79011-15:1998.

Oznaczanie zawartości tłuszczu w nasionach, owocach oleistych i śrucie poekstrakcyjnej. PN-73/R--66164.

PASIOWIEC-ŻUREK K. 2005. *Żywienie w chorobie nowotworowej.* Optymalnik, 11: 21–26.

PIJANOWSKI E. 1973. *Technologia produktów owocowych i warzywnych.* PWRiL, Warszawa.

Produkty przetwarzania olejów i tłuszczów. Estry metylowe (FAME). Oznaczanie zawartości wolnego i ogólnego glicerolu oraz mono di – triacylogliceroli. PN-EN14105:2004.

Przetwory owocowe i warzywne. Przygotowanie próbek i metody badań fizykochemicznych. Oznaczanie cukrów. PN-90/A-75101/07.

Tłuszcze roślinne jadalne. Metody badań. Oznaczanie liczby kwasowej. PN-74 /R-66165.

Tłuszcze roślinne jadalne. Metody badań. Oznaczanie liczby nadtlenkowej. PN-ISO 3960.

Tłuszcze roślinne jadalne. Surowe oleje roślinne. PN-A-869006/A1.

WHITESIDE P., MINER B. 1984. *Pye Unicam Atomic Data Book. Pye Unicam LTD.* Cambridge, England.