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# FLAXSEED AND FLAXSEED OIL QUALITY

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***Abstract:*** *Flaxseed and flaxseed oil are prone to oxidative rancidity. The aim of this study was to assess the quality of flaxseed oils extracted from flaxseed produced under different environmental conditions. The material consisted of nine samples of cold extracted oil from three flax varieties. Oilseed flax production took place at more locations from 100 m to 700 m above sea level. The organoleptic characteristics of flaxseed and flaxseed oil were evaluated on the basis of the visual observations, odor and taste. The flaxseed diseases were determined in the Laboratory for phytopathology at the Agricultural institute of Republic Srpska (abbr. Institute). The oil was extracted in the Institute's oil mill. Chemical analysis of oil included Peroxide value (PV), free fatty acids (FFA) and content of fatty acids. As flaxseed quality is highly dependent on weather conditions in the year of flax production, the influence of the extreme weather events to the seed quality traits were commented too. The results indicate that high quality flaxseed oil production is conditioned with proper farm technology, weather conditions and adequate storage. Oil rancidity and self - ignition of seed appeared in a case of improper seed storage. The presence of fungi (Fusarium oxysporum f. sp. lini) on the flaxseed can also deteriorate seed and oil taste. It happened after heavy rains in 2014. The mountain region of Petrovačko polje has better agroecological conditions for flaxseed production than lowland regions as well as better conditions for organic production. The expansion of the oilseed flax production should be accompanied by the education of farmers and potential consumers of flax products.*

***Key words:*** *flaxseed, flaxseed oil, quality*

## Introduction

Fiber flax had been a common crop throughout the Balkans until the introduction of man-made fiber. In some regions, local flax varieties were used for oil production too. The lack of interest in this plant species had lasted until the end of the past century, so most of local varieties were irretrievably lost. The international conference "Bast Fibrous Plants Today and Tomorrow" held in St. Petersburg (September 1998) was a key event of importance for the return of flax to the Balkans, this time oilseed varieties (Kondić and Nožinić, 1998). In the following years, flax varieties from the gene bank "N.I. Vavilov" in St. Petersburg were tested in the Institute's experimental field in Banja Luka. Commercial oilseed flax production (syn. linseed) has been developing after the Third Global Workshopof the FAO/ESCORENA European Cooperative Research Network on Flax and Other Bast Plants "*Bast Fibrous Plants for Healthy Life*" held in Banja Luka in 2004. As local flax varieties had been lost, the first activities were focused on the introduction of

flaxseedfrom the Agricultural Institute in Zajačar in Serbia (Garić and Mandić, 2004). Some mountain regions (Petrovačko polje, Manjača) were recognized to be suitable for "ecologically friendly" and organic oilseed flax production (Nožinić, 2009; Nožinić et al., 2012; Nožinić et al., 2013). The ecological advantages of mountain regions are due to the absence of invasive weeds as *Ambrosia artemisiifolia* and unpolluted soils (some plots have not been cultivated for 30 years). The production of cold extracted vegetable oils at the Institute began in 2011. The transfer of knowledge from the Institute to the farmers resulted in about 30 oil mills, which have been contributed to farms' incomes. As flaxseed oil shows evident functional food effects, its price on the local market is from 15 to 20 Euros per liter. However, as flax has a shallow root system, its production in the lowlands is more and more difficult for frequent droughts and global warming. Extremely high temperatures can affect seed and oil quality even before harvesting. Unlike lowlands, some mountain valleys with moderate summer temperatures, high number of sunny hours and permanent wind activity create almost ideal conditions in the period of oilseed flax ripening. Flax requires certain storage conditions. Banal mistakes, such as storing seeds in a thick layer in a plastic package can lead to product spoilage or even self-ignition. So, it is not easy to produce quality flaxseed oil and earn desired money.

The aim of this paper was to describe the quality of flaxseed oil samples extracted from flaxseed produced in different agro ecological conditions.

## Materials and methods

Analysed material consisted of nine samples of cold extracted oil from three flaxseed varieties. The first oil sample (BL-Z) was extracted from yellow seed variety Zlatko (eng. "golden") produced at the Institute's experimental field in Banja Luka. The second oil sample (BL-O) was extracted from Romanian variety Olin (brown flaxseed) harvested on the same location.

Table 1. Basic data of flaxseed production locations
Tabela 1. Osnovni podaci o proizvodnim površinama

| Location | Longitude | Latitude | Altitude (m) | Relief form |
|---|---|---|---|---|
| Banja Luka | 17.2200 | 44.7800 | About 150 | River valley |
| Vedro polje | 16.3896 | 44.5064 | 650 - 700 | Mountain valley without river |
| Vrtoče | 16.1753 | 44.6347 | About 600 | Mountain valley without river |
| Derventa | 17.9067 | 44.9792 | 150 - 200 | Gentle slopes |
| Orašje | 18.6935 | 45.0368 | About 100 | Large river valley |

Other oil samples (Table 2) originate from one local flax variety. Its origin and classification (oil or fibre form) are not clear. This seed had been stored on the old house roof in the village Vrtoče for many years, then sown in 2004. Since 2004, the seed has been multiplied on more locations with different climate conditions showing excellent adaptability. The oil sample (OR) originated from Orašje, a fertile lowland

area besides the River Sava (Table 1). Other oil samples were extracted from flaxseed produced in the region of the Petrovačko polje (abbr. PE). The abbreviation (PE-VP) is related to the seed produced in the valley Vedro Polje, which is a part of Petrovačko polje (PE). The name of this valley corresponds to its main climatic feature (high number of sunny hours). The abbreviation PE-V is related with the village Vrtoče in the central part of Petrovačko Polje. The spreading of local variety began by the enthusiast Miodrag Latinović from that village. The organoleptic flaxseed properties were evaluated on the basis of the visual flaxseed characteristics (smooth or wrinkled seed surface, seed gloss, seed size, visible traces of pathogens or pathogen activity on seeds), odor and taste. The diseases were determined in the Institute's Laboratory for phytopathology. The oil was extracted in the Institute's oil mill. Chemical analyses of oil have been done by the Laboratory of "Bimal Group" in Brčko. Peroxide value (PV) was determined by method ISO 3960, free fatty acids (FFA) were determined according to ISO 660 and content of fatty acids by GC methodology (ISO 5508, 5509).The influence of the extreme weather events to the seed quality traits was described on the basis of climatic data from the meteorological stations Banja Luka and Drinić - Petrovac.

## Results and disscussion

Proper farming technology is a key precondition for quality flaxseed. Because of the weak root system and specific ecological requirements in the ripening period, oilseed flax belongs to the crops which are very vulnerable to the extreme weather conditions. In some years, flaxseed harvest gives a "headache" to the most experienced harvesters. Each damage of flaxseed during the harvest leads to fast spoilage. Some weed seeds or weed tissues release a strong smell or contain toxic compounds (Janjić et al., 2008), so these impurities must be removed from flaxseed immedetialy after harvesting.

Experienced digester can assess flaxseed quality on the basis of organoleptic traits. In some cases (oil for personal consumption), similar methodology is acceptable for assessing flaxseed oil quality. If the oil is intended for broad market, this "Grosso modo" test must be enhanced with chemical analysis. As flaxseed and flaxseed oil are prone to oxidation processes, the Peroxide value (PV) is considered as the most reliable indicator of the potential oxidative rancidity (stability). According to the domestic legislation, the allowed amount of peroxide oxygenis up to 15 meq per kg of oil. Free fatty acids are limited to 2%. Potential manipulations with vegetable oil mixtures can be detected by a fatty acid test.

Two oil samples (BL-Z, BL-O) from the seed harvested at the Institute's experimental field in Banja Luka in 2009 had excellent taste, low PV and FFA percentage, which indicated proper seed and oil management. That year was relatively suitable for oilseed flax production. Typical June with high rainfall (Banja Luka, 153 $l/m^2$) provided satisfactory conditions for normal growth, pollination and seed development. Though frequent rains caused occurence of new flowers for longer periods (partial retrovegetation), dry and hot weather in July favored uniform flaxseed

ripening. The Serbian variety Zlatko was released in 2003 in the Agricultural Institute in Zajačar (Stanković et al., 2003), then tested in Banja Luka region in the period 2006 - 2014. Unfortunately, this valuable variety was lost during the flood in 2014. Romanian variety Olin provided excellent oil yields in the mountain region of Manjača (village Sitnica). This oil had a very "soft" taste, acceptable for consumers.

The quality of flaxseed in 2013 was highly dependent on harvest date. Better seed quality was obtained when the harvest was done till the mid of July. The flaxseed from Orašje (OR), which was harvested on July 12 provided oil with excellent taste as well as desirable PV and FFA percentage (Table 2). The flaxseed that was maturing in the second part of July and in the first part of Avgust was exposed to extreme heat. In the third decade of July 2013, the lowland regions experienced maximum temperatures about 40˚C (Banja Luka, 41.6˚C). Hellish heat and intensive insolation continued in Avgust causing partial oxidative spoilage of flaxseed in the field.

The year 2014 can rightly be called the "Black year" for oilseed flax production. Heavy rains in the period April - September (Banja Luka, 944 lit/$m^2$; Drinić - Petrovac, 1.246 lit/$m^2$) led to the development of serious flax diseases (flax wilt), which caused the decay of plants in the period of emergence as well as rapid reduction of flaxseed yield and quality. The unprecedented flood in April 2014 strangled the flax in the varietal trial at the Institute's experimental field in Banja Luka. Small quantity of flaxseed harvested in 2014 had significantly lower germination in 2015. Flax survived stress conditions in 2014 just on a few plots with permeable soils in the mountain region of Petrovačko polje. The oil from one sample of the flaxseed produced in 2014 was analysed in 2015. Although the content of PV and FFA indicated relative good oil quality (table 2), the laboratory assistant commented flaxseed oil organoleptic traits in this way "I do not like this taste, feel burning in the throat". It seems, other factors (in this case flax disease) deteriorated flaxseed oil quality. Almost all oilseed flax fields in 2014 were infested by *Fusarium oxysporum*, which is a common fungi in the humid conditions. Fusarium wilt caused by *Fusarium oxysporum* f. sp. lini (Fol), can infect flax at any growth stage and may result in 100% disease incidence in certain cultivars (Panjan, 1968; Kommedahl et al., 1970). The pathogen which can be seed-borne or soil-borne, invades through roots and develops in the xylem. Radman (1978) states that this pathogen makes more damage on oilseed flax varieties than fiber ones. Very high content of linolenic fatty acid (omega - 3) in the oil from the seed harvested in 2014 might be the result of extremely long vegetation. The longer vegetation, the higher the content of polyunsaturated fatty acids in oil crops (Kastori, 1991).

Table 2. Results of flaxseed oil analyses
Tabela 2. Resultati analize lanenog ulja

| Sample | Harvest | Analysed | PV | FFA | C18:3 | C18:2 | C18:1 | C18:0 | C16:0 |
|---|---|---|---|---|---|---|---|---|---|
| BL-Z | 2009 | April, 2010 | 0.31 | 0.69 | 56.0 | 15.2 | 18.0 | 3.6 | 5.2 |
| BL-O | 2009 | April, 2010 | 0.21 | 0.51 | 54.2 | 12.6 | 20.6 | 4.4 | 5.8 |
| OR | 2013 | Sept., 2013 | 1.74 | 0.21 | 50.3 | 12.4 | 25.5 | 4.4 | 6.1 |
| PE-V | 2014 | March, 2015 | 2.99 | 0.29 | 61.7 | 14.7 | 15.3 | 3.6 | 4.5 |
| PE-V | 2019 | Dec., 2019 | 0 | 0.36 | 59.6 | 12.9 | 17.6 | 3.5 | 5.5 |
| PE-VP | 2020 | Jan., 2021 | 0.66 | 0.64 | 60.1 | 12.3 | 18.9 | 3.6 | 4.7 |
| PE-VP | 2019 | Jan., 2021 | 0.34 | 0.43 | - | - | - | - | - |
| PE-VP | 2018 | Jan., 2021 | 10.46 | 3.20 | | | | | |
| DE | 2020 | March, 2021 | 15.03 | 4.11 | 53.2 | 12.9 | 18.1 | 3.5 | 4.9 |

Perfect flaxseed oil was produced from the flaxseed harvested in the village Vrtoče (PE-V) in 2019 (Table 2). Total absence of the reactive oxygen in this oil sample indicates proper production technology and proper oil storage. This farmer produces flax using organic manure from own dairy farm, has own harvester and small oil mill. Thanks to proper field production technology and absence of invasive weeds (*Ambrosia sp.*), there is no need for herbicide treatment. In fact, it is an organic model of production without certification. As all activities "from the field to the oil" take place under full farmer's control, all production risks are reduced to minimum.

Oil sample from Vedro polje from the oldest flaxseed (PE-VP, harvested in 2018) showed signs of hydrolytic rancidity followed by an unpleasant taste. This seed was harvested three years before the oil extraction. Hydrolitic rancidity can develop in the quality oil too, if the oil lies on the sedimented remains of flaxseed for a longer period. This flaxseed sediment always contains a certain percentage of water which can react with oil causing hydrolytic rancidity. Other oil samples from Vedro polje had excellent quality. The name of the valley (Vedro polje) indicates desirable environmental condition for oilseed flax production. However mountain agriculture has its challenges too. Flax fields close to deep mountain forests sometimes share the forest inhabitants' rules. So massive gray bears enjoy rolling on flax field, while herds of wild pigs trample flax and other crops. Birds can invade flax in the phase of cotiledones and in the phase of ripening.

Oilseed flax has the highest needs in water during the phases of the intensive growth and flowering in May and June. Since June 2021 was the driest one (Banja Luka 12 lit/$m^2$) in the period of measurements (Banja Luka, since 1881), shallow root system of flax could not provide enough water for normal flax growth and pollination.

Moderately warm and sunny weather in July stimulates oil synthesis and ripening of flaxseed. However, July 2021 brought hellish heat (Banja Luka, max. 40.2˚C), which caused shrinking of flaxseed and negligible yield. Once more, the local market is faced with the lack of locally produced flaxseed oil. These few examples show negative effects of extreme weather conditions to flax production.

Improper flaxseed storage can cause spoilage and great damage. In the first case, large amount of flaxseed harvested in the hilly region of Derventa (DE), then stored in the polypropylene (PP) jumbo bags (one tonne loading capacity) rapidly changed taste after a few months. Visually, the seed looked normal. However, the oil from this seed had a bitter taste, too high PV and FFA percentage (Table 2). Rancid oil can be used for natural protection and decoration of woody surfaces. However, painting demands high care as an oiled cloth or paint brush can ignite spontaneously and cause a fire. The second example of improper storage practice coms from the mountain region of Petrovačko polje. Once more, the problem arose in a PP jumbo bag containing 2.5 tons of seed. Unlike the first example when the seed maintained shiny look, the self - ignited seed was practically burned. Both producers learned the lesson about flaxseed oxidation risks on their own mistakes.

Let us end this discussion with evident environmental advantages for oilseed flax production in the region of Petrovačko polje. Compared with the lowlands, that mountain region has more sunny hours and less foggy days. Rich mountain relief and closeness of the Adriatic Sea create permanent winds' activity. The more air circulation, the less plant diseases appeare. Unlike lowlands, the temperatures in the mountain valleys rarely exceed 30˚C. Such moderate temperatures favor longer oil synthesis providing oil with a very high content of polyunsaturated fatty acids (omega-3). The fact is that Petrovačko polje meets all conditions for the flaxseed products with geographical origin.

## Conclusion

Flaxseed oil quality is highly dependent on proper farm technology and environmental conditions. Petrovačko polje provides better agro ecological conditions for oilseed flax production than lowlands. As oilseed flax is very sensitive to the extreme weather conditions, farmers should care of seed reserve for the next year.

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# KVALITET LANA I LANENOG ULJA

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***Sažetak:*** *Laneno sjeme i laneno ulje skloni su oksidativnom kvarenju. Cilj ovog istraživanja bio je ocijenjivanje kvaliteta hladno cijeđenog ulja dobijenog iz lana proizvedenog u različitim agroekološkim uslovima. Analizirani materijal sastojao se od devet uzoraka hladno cijeđenog ulja. Proizvodnja uljanog lana odvijala se na više lokaliteta od 100 m do 700 m nadmorske visine. Organoleptička svojstva lanenog sjemena i lanenog ulja ocjenjivana su na osnovu vizualnih opažanja, mirisa i okusa. Bolesti sjemena lana utvrđene su u Laboratoriji za fitopatologiju Poljoprivrednog instituta Republike Srpske (skraćeno Institut). Ulje je cijeđeno u Institutskoj uljari. Hemijska analiza ulja uključivala je peroksidni broj (PV), slobodne masne kiseline (FFA) i sadržaj masnih kiselina. Kako kvalitet lanenog sjemena značajno ovisi o vremenskim uslovima u godini proizvodnje lana, komentiran je i uticaj ekstremnih vremenskih prilika na osobine kvalitete sjemena. Rezultati pokazuju da je kvalitetna proizvodnja lanenog ulja uslovljena odgovarajućom tehnologijom uzgoja, vremenskim prilikama i odgovarajućim skladištenjem. Užeglo ulje i samozapaljenje sjemena javlja se u slučaju nepravilnog skladištenja sjemena. Prisutnost gljivica (Fusarium oxysporum f. sp. lini) na sjemenu lana također može pogoršati okus sjemena i ulja, što se dogodilo nakon obilnih kiša u toku 2014. godine. Područje Petrovačkog polja pruža povoljnije agroekološke uslove za proizvodnju lanenog sjemena od nizinskih područja, kao i bolje uslove za organsku proizvodnju. Širenje proizvodnje lana i lanenog ulja treba biti praćeno edukacijom proizvođača i potencijalnih kupaca lanenih proizvoda.*

***Ključne riječi:*** *laneno sjeme, laneno ulje, kvalitet*