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Comparison of the lipid content and fatty acid composition of two hulled oats and their hull with naked and dehulled oats varieties

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Abstract: Oat (*Avena sativa* Linnaeus) has distinctive multifunctional characteristics and nutritional profile, as well as a large amount of oat-processing by-product comprises hulls, which contain lipids and other nutrients. In this study, the lipid content and fatty acid (FA) profiles of six naked oat varieties (Kamil, Marco Polo, Oliver, Patrik, Santini, and Saul), two hulled oat varieties (Atego and Korok), and their dehulled grains and hulls were analysed. The findings of the study demonstrated that the lipid content varied from 4.14 g·100 g^{-1} dry matter (DM) (Santini) to 6.68 g·100 g^{-1} DM (Kamil) in naked oats; 3.61 g·100 g^{-1} DM in Atego and 3.47 g·100 g^{-1} DM in Korok with hull; 0.70 g·100 g^{-1} DM in Atego hull and 0.71 g·100 g^{-1} DM in Korok hull. Dehulled oats had a higher lipid content than hulled oats. Linoleic and oleic acids were the predominant FAs in analysed samples. Oat hulls contained maximum amounts of saturated FAs (SFAs) (26% in Korok and 25.6% in Atego). Elimination of hulls raised the amount of linoleic acid and decreased the amount of oleic acid. Oat hull contained the least amount of linoleic acid and the highest amount of C20:0 (eicosanoic acid) and C22:0 (docosanoic acid). Oats are a significant source of lipids, predominantly comprising unsaturated fatty acids (UFAs). Moreover, oat hulls contribute to the lipid content although their FA composition, with higher palmitic acid and lower linoleic acid levels, differs from that of naked, hulled, and dehulled oats.

Keywords: *Avena sativa*; oat by-products; oat hulls lipid content; lipid composition

Wheat, rice, and maize are the leading cereals regarding global production, whereas oats (*Avena sativa* Linnaeus, 1753) rank sixth. Oats have historically mostly been used as animal feed, especially for horses. However, as interest in the possible use of oats for human nutrition has grown, this practice has been steadily declining (Ahmad et al. 2010). Oat crops have drawn more attention due to the growing popularity of plant-based diets and the health advantages they are linked to. According to recent data 25.05 million metric tons of oats were produced globally in 2022/23 (Shahbandeh 2023). Essentially, there are two types of oats: hulled oats, where the oat kernel or caryopsis is surrounded in a hardened lemma, and palea,

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commonly known as the hull. After harvesting, these hulls need to be removed. In contrast, naked oats belong to the same species as hulled oats but exhibit considerably less lignification in their lemma compared to hulled oats. This reduced lignification results in a lemma that is less thick and not as tightly curved around the kernel, making it easier to separate the kernel at harvest time (Hackett 2018).

Oat hulls, which make up about 25–35% of the weight of oat seeds, are essential for shielding kernels from fungal diseases and threshing. Although dehulling oats raises industry costs, naked oats offer a more affordable option. Additionally, like cereal straw in terms of protein and calorie content, oat hulls provide beneficial nutrition to livestock, such as cattle, sheep, and horses (Jawad et al. 2013).

Oat hulls have potential applications in biorefinery operations, the creation of bio-based packaging materials, and construction composites in addition to animal feed. According to Schmitz et al. (2020) burning rice and oat husks at 950 °C produces calcium hydroxide, which improves the calcination characteristics of cement. Although disposing of oat hulls, the main by-product of oat milling, is a problem worldwide, they can be used to produce hydrogen, extract cellulose, and produce furfural and food-grade fiber (Girardet and Webster 2011; Menon et al. 2016; Oliveira et al. 2017).

Oat hulls are made up of cellulose, hemicellulose, lignin, ash, protein, and fat, and they mostly comprise the cell wall (Welch et al. 1983). Oat hulls, which are rich in lignin, are used in animal feed to enhance energy intake and support gut health by promoting a balanced microbiota and strengthening gut barrier integrity. A 3% oat husk diet can improve development and carcass weight costs for broiler chickens (Den Besten et al. 2013; Ndou et al. 2018; Adewole et al. 2020). The use of oat hulls in animal husbandry can lead to cost savings.

Oat grains contain higher levels of protein and crude lipid content than other cereals. The elevated lipid content in oats serves as a significant energy source and provides unsaturated fatty acids (UFAs). While linoleic, oleic, and palmitic acids are the predominant fatty acids (FAs) in both naked and hulled oats, their relative proportions vary (Pokhrel et al. 2022). The composition of oat lipids has been documented to consist of 51% triacylglycerols, 7% free fatty acids, 3% sterols, 3% sterol esters, 8% glycolipids, and 20% phospholipids. Additionally, oat lipids are categorised into two types: polar and non-polar fractions. The majority (around 80%) of the lipids are non-polar and contain valuable fatty acids such as palmitic acid, oleic acid, linoleic acid, and fat-soluble antioxidants (Sahasrabudhe 1979). Four different batches of oat hulls grown in comparable areas but with different climatic conditions had lipid levels ranging from 0.5 to 1.5 g·100 g^{-1} (Schmitz et al. 2020). The concentrations of SFAs 18:1 and 18:2 ranged from 24 to 36.5 g·100 g^{-1} (mean 30.4 g·100 g^{-1}), 25.7 to 36.3 g·100 g^{-1} (mean 29.4 g·100 g^{-1}), and 28.8 to 35.8 g·100 g^{-1} (mean 31.7 g·100 g^{-1}) in seven distinct Swedish oat husk samples. Additionally, the authors noted that the hulls' average total lipid content was 3 g·kg^{-1} dry matter (DM) (Bryngelsson et al. 2002).

In the previous paper, the lipid content and FA composition of naked and hulled oats with and without hulls was evaluated (Kourimska et al. 2021). However, information about the lipid content and FA composition of oat hulls was missing there. Thus, the objective of this study was to evaluate the lipid content and FA composition of the hulls of two hulled oats and compare them with naked oats and dehulled oat grains. We additionally scrutinised the impact of dehulling on the FA profile of oat grains.

MATERIAL AND METHODS

Oat samples

The oat samples utilised in the present study were provided by the Selgen a.s. breeding station (Stupice, Czech Republic). The oat varieties used in this study were registered between 2002 and 2018. Of the eight yellow varieties, two (Atego and Korok) were hulled oats and six (Kamil, Marco Polo, Oliver, Patrick, Santini, and Saul) were naked oats. All these samples have been described in Table 1.

Post-harvest sample characteristics. The post-harvest characterisation of the samples was undertaken using a FOSS Infratec 1241 grain analyser (FOSS Analytical A/S, Hillerød, Denmark) that quantified essential quality parameters for procurement, including total protein and moisture content. Each sample was measured ten times, with a relative standard deviation of the method below 1%. The post-harvest characteristics of the samples are also given in Table 1.

Sample preparation and evaluation of lipid content. In the case of hulled oats, grains, and hulls were separated manually to prevent breakage and avoid mixing oat grains or their parts with the hulls. From 30 g hulled oats of the Atego and Korok varieties, 7.3 and 7.6 g hulls, respectively, were obtained, with a grain-to-hull ratio of approximately 4:1. The separated hull, hulled oats, dehulled oat grains and naked oats were

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Table 1. Descriptions and post-harvest characterisation of analysed yellow oat samples

Oat cultivar	Origin	Registration year	Protein content	Moisture content
			(g·100 g^{-1})	
Atego (hulled)	Gramena × Auron	2002	14.91	11.36
Korok (hulled)	Atego × KR 93682	2011	14.39	10.22
Kamil (naked)	Izak × (10029 Cn × KR 9478)	2012	18.10	9.71
Marco Polo (naked)	Tibor × Atego	2018	18.36	9.80
Oliver (naked)	(vL8250 × D16/84) × (Jumbo × KR 90–40)	2012	17.41	9.80
Patrik (naked)	Avenuda × (Azur × Master)	2015	15.66	9.93
Santini (naked)	Tibor × Atego	2018	17.49	9.82
Saul (naked)	(Dragon × S 16908) × KR 5278	2006	17.72	9.89

Post-harvest characterisation n = 10, relative standard deviation (RSD) ≤ 1%

then grounded for three min using a Scarlett Silver Line SL 1545 coffee grinder (Ariette-Scarlett, Firenze, Italy). Ground samples, weighing approximately 15 g, were placed in high-performance cellulose extraction thimbles of Cytiva Whatman grade and sealed with cotton. The lipid was obtained following the procedure documented by (Kourimska et al. 2018) using petroleum ether 40–65 °C (VWR®) in a Soxhlet extraction apparatus (Carl Roth, Germany) for four hours. The same petroleum ether extraction procedure was used to determine the lipid content and subsequent the FA composition analysis. A rotary vacuum evaporator (Heidolph Hei-VAP Core HL G3; Heidolph Instruments GmbH, Schwabach, Germany) was utilised to evaporate petroleum ether at the temperature of 35 °C. The lipid content was quantified gravimetrically following drying at 103 ± 2 °C until reaching constant weight. Each sample was analysed in triplicate.

Evaluation of fatty acid composition. The method detailed in (Kourimska et al. 2018) was employed to analyse the FA composition of the samples. Nearly half grams of lipid was re-esterified and analysed in accordance with ISO 12966-2:2011 specifications, utilising gas chromatography-mass spectrometry (GC-MS) on an Agilent 7890 (Agilent Technologies). Each extract was prepared three times and injected twice to ensure accuracy and precision. Methylated FAs were detected with the Restek Food Industry FAME mix (cat#35077) and compared to mass spectra available in the National Institute of Standards and Technology Library (NIST) database in the USA. The relative quantity of FAs was calculated through the area normalisation method and then presented as a percentage of total identified FAs.

Statistical evaluation. Statistical evaluation comprised one-way analysis of variance (ANOVA) conducted with IBM SPSS Statistics 29.0.0.0 (Armonk, New York, USA), with a level of significance of P = 0.05. The average ± standard deviation was assessed using Tukey's HSD (honestly significant difference) test.

Table 2. Lipid content in naked oats, hulled oats with and without husks, and husks from hulled oats

Sample	Fat content	Fat in DM content
	(g·100 g^{-1})	
Atego after dehulling	4.13 ± 0.32^{bcde}	4.62
Atego before dehulling	3.20 ± 0.19^{e}	3.61
Atego hull	0.63 ± 0.12^{f}	0.70
Kamil	6.03 ± 0.37^{a}	6.68
Korok after dehulling	4.27 ± 0.29^{bcde}	4.71
Korok before dehulling	3.21 ± 0.09^{de}	3.47
Korok hull	0.68 ± 0.06^{f}	0.71
Marco Polo	4.29 ± 0.17^{bcde}	4.67
Oliver	4.60 ± 0.23^{bc}	5.10
Patrik	5.27 ± 0.38^{ab}	5.85
Santini	3.73 ± 0.21^{cde}	4.14
Saul	4.48 ± 0.20^{bcd}	4.97

DM – dry matter; values are expressed as mean ± standard deviations (SD); number of replication (n = 3); mean values with different superscript letters were significantly different (P > 0.05)

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RESULTS AND DISCUSSION

Lipid content. The lipid content of naked and hulled oats, as well as their hulls and dehulled oat grains, is presented in Table 2. The findings revealed that naked oats had a higher lipid content than hulled oats, with or without hulls, excluding naked Santini which had a lower lipid content than both the hulled cultivars before dehulling. The lipid content observed in naked oats ranged from 4.14 to 6.68 g·100 g^{-1} DM, aligning with previous studies conducted by various researchers (Kourimska et al. 2018, 2021; Capouchova et al. 2020).

Among the naked oat cultivars, Kamil demonstrated the topmost lipid content (mean 6.68 g·100 g^{-1} DM), followed by Patrik (5.85 g·100 g^{-1} DM). In contrast, Santini had significantly lower lipid content as compared to Kamil, with values of 4.14 g·100 g^{-1} DM. Hulled Atego had the lowest lipid content (3.61 g·100 g^{-1} DM) among all the tested oat varieties. Dehulling of Korok and Atego hulled oats increased the lipid content of the grains compared to most naked oats. The lipid content in the Atego hull was 0.70 g·100 g^{-1} DM, while in the Korok hull, it was 0.71 g·100 g^{-1} DM.

Concerning Patrik, the reported lipid content values of 5.59 g·100 g^{-1} DM (Kourimska et al. 2018) and 6 g·100 g^{-1} DM (Capouchova et al. 2021) are consistent with the present study outcomes. Additionally, the lipid content of naked oats, as observed by Boeck et al. (2018), was higher for Oliver (6.02 g·100 g^{-1}), Kamil (7.36 g·100 g^{-1}), and Saul (5.41 g·100 g^{-1}) compared to present study. Several variables, including location and year, genetics, harvesting time, soil type and nutrition, and post-harvest treatments, could be responsible for the observed difference. Furthermore, oats high lipid content indicates a higher risk of rancidity and the possibility of sticking during the milling process. Notwithstanding these possible disadvantages, oats' FA content makes them extremely beneficial for human consumption. Consequently, high lipid oats are regarded as an indicator of quality in oats as discussed by (Decker et al. 2014).

Furthermore, the lipid content of hulled oats, Atego, and Korok before dehulling was approximately 3.5 g·100 g^{-1} DM. The lipid content of Korok was reported at 2.85 g·100 g^{-1} DM Kourimska et al (2018), which aligns with the current findings. They added that the value rose to 4.31 g·100 g^{-1} DM once the hull was removed. A similar phenomenon can be observed in the current study, upon hull removal the value of lipid content reached 4.71 g·100 g^{-1} DM in dehulled Korok grain. Similarly, after dehulling, the value reached 4.62 g·100 g^{-1} DM in dehulled Atego grain. Notably, when comparing the lipid content of dehulled oat grains to naked oats, it is crucial to highlight that both have comparable lipid content. Additionally, Atego oat hulls contained 0.70 g·100 g^{-1} DM of lipid, while Korok had 0.71 g·100 g^{-1} DM. Research conducted by Welch et al. (1983) discovered a higher lipid content (1–2.2 g·100 g^{-1}) in oat hulls than in the current study.

The lipid content results differ from those in previous studies by (Banas et al. 2007) reporting lipid contents of 7–11 g·100 g^{-1}, and (Flander et al. 2007) revealing 5–9 g·100 g^{-1} lipid contents in oats. According to these authors, oats had a higher lipid content in comparison several other grains, such as durum wheat, common wheat, rye, barley, and triticale.

Fatty acid composition. The FA compositions of hulled oats, their hulls, and dehulled oat grains are illustrated in Table 3. As expected, the most remarkable FAs identified in the analysed samples were linoleic acid (C18:2 *cis cis*–9.12), oleic acid (C18:1 *cis*–9), and palmitic acid (C16:0), and their sum ranged from approximately 91.2–96.6% in oats and 88% in oats hulls. Steric acid (C18:0) and α-linolenic acid (C18:3 all-*cis*–9; 12; 15) were also present in reasonable amounts. Additionally, other FAs were also detected and quantified, such as C14:0, C16:1 *cis*–9, C17:0, C17:1 *cis* 10, C20:0, C20:2 *cis, cis*–11;14, C22:0, C22:1 *cis*–13, C24:0, C24:1 *cis*–15, with contents ranging from 0.01 to 0.99%. Some exceptional cases can be observed in the hulls.

The hulled oats, Korok and Atego, contained 21.3% and 21.6% of palmitic acid, 34.8% and 36% of oleic acid, and 23.4% and 33.9% of linoleic acid, respectively. Differences were observed in hulled and naked oats. The concentration of oleic and linoleic acid was less in hulled oats than in naked oats, which is consistent with previous research of (Kourimska et al. 2018). Specifically, Patrik a naked oat contained the highest oleic acid in the studied samples, and it had significant differences not only with hulled oats but also with dehulled oat grains and hulls. Similarly, the content of stearic acid in Kamil (naked oat) is higher and differs significantly from hulled oats and dehulled oat grains.

Moreover, this study investigated the impact of hull removal on the FA composition. Upon the removal of the hull, discernible alterations in FA composition were noted. The distribution of SFAs, oleic acid, and linoleic acid in Atego hulls were 30.9%; 35.4% and 29.6%; respectively. In Korok hull, the percentages were 33.2% for SFAs, 34.7% for oleic acid, and 28.3% for linoleic acid. The palmitic acid in dehulled Korok grain de-

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Table 3. Composition of fatty acids in hulled oats with and without husks, and hulls (in % of all fatty acids)

Fatty acid	Atego	Atego hull	Dehulled Atego grain	Dehulled Korok grain	Korok	Korok hull
C14:0	0.46 ± 0.05^{cd}	1.00 ± 0.18^{b}	0.51 ± 0.1^{cd}	0.56 ± 0.02^{dc}	0.57 ± 0.08^{cd}	1.34 ± 0.09^{a}
C16:0	21.58 ± 0.81^{ab}	23.23 ± 1.64^{ab}	26.17 ± 2.23^{a}	20.87 ± 0.31^{bc}	21.34 ± 1.69^{ab}	24.81 ± 0.18^{ab}
C16:1 *cis*-9	0.28 ± 0.09^{b}	0.49 ± 0.02^{b}	0.34 ± 0.07^{b}	0.33 ± 0.00^{b}	0.46 ± 0.22^{b}	0.90 ± 0.02^{a}
C17:0	0.09 ± 0.00^{b}	0.26 ± 0.00^{b}	0.10 ± 0.02^{b}	0.99 ± 0.00^{a}	0.15 ± 0.00^{b}	0.50 ± 0.11^{b}
C17:1 *cis*-10	0.04 ± 0.00^{b}	ND	0.05 ± 0.00^{b}	ND	0.31 ± 0.07^{b}	ND
C18:0	2.46 ± 0.20^{bcd}	2.99 ± 0.35^{bc}	2.42 ± 0.55^{bcd}	1.93 ± 0.05^{cd}	2.68 ± 0.09^{bcd}	3.52 ± 0.08^{ab}
C18:1 *trans*-9	0.87 ± 0.11^{ab}	1.58 ± 0.29^{a}	ND	ND	1.41 ± 0.13^{ab}	ND
C18:1 *cis*-9	35.99 ± 1.93^{bc}	35.40 ± 2.19^{bc}	30.11 ± 1.57^{d}	33.73 ± 1.17^{cd}	34.85 ± 0.40^{bc}	34.78 ± 1.10^{bc}
C18:2 *cis, cis*-9,12	33.91 ± 0.40^{abc}	29.66 ± 3.11^{c}	35.35 ± 3.56^{ab}	38.32 ± 0.72^{a}	35.43 ± 1.38^{ab}	28.35 ± 0.61^{c}
C20:0	0.42 ± 0.07^{b}	1.28 ± 0.26^{a}	0.28 ± 0.08^{b}	0.22 ± 0.01^{b}	0.29 ± 0.07^{b}	1.08 ± 0.09^{a}
C18:3 all *cis*-9,12,15	2.22 ±0.35^{a}	1.54 ± 0.17^{b}	3.57 ± 0.71^{a}	2.88 ± 0.05^{a}	1.75 ± 0.00^{b}	2.70 ± 0.00^{a}
C20:2 *cis, cis*-11,14	ND	ND	0.08 ± 0.01	0.09 ± 0.00	ND	ND
C22:0	0.72 ± 0.32^{bc}	1.69 ± 0.27^{a}	0.33 ± 0.11^{c}	0.36 ± 0.03^{c}	0.25 ± 0.00^{c}	1.32 ± 0.05^{ab}
C22:1 *cis*-13	0.22 ± 0.09	ND	0.27 ± 0.05	0.19 ± 0.00	0.21 ± 0.02	ND
C24:0	0.23 ± 0.07^{b}	0.53 ± 0.05^{a}	0.31 ± 0.10^{b}	0.27 ± 0.01^{b}	0.30 ± 0.02^{b}	0.67 ± 0.05^{a}
C24:1 *cis*-15	0.18 ± 0.01^{a}	ND	0.15 ± 0.04^{ab}	0.12 ± 0.00^{abc}	ND	ND
Σ SFA	25.96 ± 1.43^{bcd}	30.97 ± 3.37^{ab}	30.12 ± 3.16^{abc}	24.31 ± 0.27^{bcd}	25.58 ± 1.60^{bcd}	33.23 ± 0.80^{a}
Σ MUFA	39.79 ± 2.06^{ab}	39.00 ± 1.40^{ab}	22.03 ± 2.24^{c}	37.25 ± 1.07^{bc}	38.99 ± 0.53^{ab}	38.38 ± 1.07^{abc}
Σ PUFA	33.91 ± 0.40^{bc}	29.66 ± 2.11^{c}	47.83 ± 2.93^{ab}	38.41 ± 0.72^{a}	35.43 ± 1.38^{ab}	28.35 ± 0.61^{c}

n = 3; ND – not detected; values are expressed as mean ± standard deviations (SD); mean values with different superscript letters in the same row were significantly different ($P > 0.05$); SFA – saturated fatty acids; MUFA – monounsaturated fatty acid; PUFA – polyunsaturated fatty acid

clined to 20.9%, whereas in dehulled Atego grain, it increased and reached the maximum among all the samples, including naked oats, at 26.2%. The proportion of oleic acid also declined upon hull removal, with a significant decrease in Atego, approximately by 6%, indicating a significant difference in monounsaturated fatty acid (MUFAs) levels. When comparing the dehulled oat grains and hulls significant differences can be seen in linoleic acid. These findings are consistent with a prior study by Bryngelsson et al. (2002), which documented a range of 30.4% for SFAs, 29.4% for oleic acid, and 31.7% for linoleic acid in an aggregate of Swedish oat hull samples.

When the Korok oat's hull is removed, linoleic acid levels increase but the distribution of oleic, palmitic, and stearic acids decreases. For Atego, removing the hulls resulted in a considerable decrease in oleic acid and an increase in the relative amount of linoleic and palmitic acids. However, hull removal dramatically increased the amount of linoleic acid while drastically decreasing the percentage of palmitic and stearic acids Biel et al. (2014). Furthermore, Liu (2011), compared the fatty acid profiles of hulled and dehulled oat grains and found that the latter exhibited a 4% increase in oleic acid (from 32.3 to 36.5%) and nearly double the lipid content, whereas palmitic, stearic, linoleic, and linolenic acids significantly dropped. Furthermore, 42.2% linoleic acid was found in hulled and 40.3% in dehulled oat grains, according to the author.

Except for Saul and Santini, dehulled Atego grain had a higher amount of palmitic acid than dehulled Korok grain and naked oats. Furthermore, linoleic acid increased from 35.4% to 38.3% in dehulled Korok grain and from 33.9 to 35.3% in dehulled Atego grain as a result of hull removal. The amounts of linoleic acid in hulled and dehulled oats were similar to those in naked oats (33–38%). Unlike the present study, Biel et al. (2014) found that hulled oats had a lower linoleic

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acid content, which was 28% and increased to 32% upon hull removal, while naked oats contained 34% linoleic acids. The finding of the current study aligns with the earlier observations by (Kourimska et al. 2021), who also observed an increase in linoleic acid concentration after hull removal. Furthermore, polyunsaturated fatty acids (PUFAs) – which include linoleic acid – act as a precursor to eicosanoids, which are hormone-like chemicals that are essential for maintaining the body's physiological equilibrium. Examples of these include prostaglandins and leukotrienes. While a lack of linoleic acid can result in atherosclerosis, it has a beneficial effect on the blood serum of those with diabetes mellitus. Between 5 and 8% of total calories should be consumed as linoleic acid (Batalova et al. 2019).

Oat hulls contained a comparable FA profile to other samples, although some variations can be observed. Hulls contained a relatively high amount of palmitic acid but less than dehulled Atego grain. Similarly, hulls are also rich in stearic acid compared to hulled oats and dehulled oat grains. Interestingly, all the samples, including naked oats, contained less than 1% of myristic (C14:0), arachidic (C20:0), and behenic (C22:0) acids while both hulls exceeded 1% of these FAs, making the hulls rich in SFAs. Additionally, oat hulls contained significantly lower amounts of linoleic acid (approximately 29%), and they differ from the other samples.

The FA compositions of naked oats are presented in Table 4. Naked oats contained a lower amount of palmitic acid (19.4–21.8%) in comparison to hulls, dehulled oat grains, and hulled oats, which is in agreement with Biel et al. (2014). Among naked oats, Saul contained the highest proportion of palmitic acids. However, the current study showed higher palmitic acid levels than (Batalova et al. 2019), who studied seven oat cultivars reporting 15.34% to 17.41% palmitic acid. Almost comparable ranges of oleic and linoleic acid concentrations were observed in naked oats at 36.2–39.3% and 33.1–38.02%, respectively. The FA composition in the current study aligns with (Krasilnikov et al. 2018) who investigated the seven types of naked oats intended for breeding purposes, showing similar proportions of palmitic (15.3–17.8%), oleic (33.5–36.7%), and linoleic (36.2–38.7%) acids. The linoleic to oleic acid ratio is close to one suggesting that oat oil can be categorised within the oleic-linoleic

Table 4. Composition of fatty acids in naked oats (in % of all fatty acids)

Fatty acid	Kamil	Marco Polo	Oliver	Patrik	Saul	Santini
C14:0	0.28 ± 0.10^{d}	0.47 ± 0.08^{dc}	0.58 ± 0.22^{cd}	0.39 ± 0.10^{cd}	0.63 ± 0.11^{c}	0.51 ± 0.17^{cd}
C16:0	20.09 ± 0.71^{bc}	19.65 ± 0.87^{bc}	20.56 ± 0.08^{bc}	19.44 ± 0.98^{c}	21.79 ± 0.98^{ab}	21.01 ± 0.75^{ab}
C16:1 *cis*-9	0.36 ± 0.10^{b}	0.48 ± 0.09^{b}	0.48 ± 0.12^{b}	0.44 ± 0.10^{b}	0.39 ± 0.06^{b}	0.39 ± 0.01^{b}
C17:0	0.08 ± 0.03^{b}	ND	0.15 ± 0.04^{b}	0.68 ± 0.18^{a}	ND	0.10 ± 0.01^{b}
C17:1 *cis*-10	0.05 ± 0.01^{b}	ND	0.09 ± 0.01^{b}	ND	0.03 ± 0.01^{b}	1.03 ± 0.27^{a}
C18:0	4.62 ± 0.89^{a}	1.80 ± 0.20^{cd}	1.99 ± 0.67^{cd}	0.92 ± 0.65^{d}	2.63 ± 0.46^{bcd}	1.88 ± 0.09^{cd}
C18:1 trans-9	ND	ND	ND	0.10 ± 0.07^{b}	ND	ND
C18:1 *cis*-9	37.99 ± 0.83^{ab}	37.21 ± 0.06^{abc}	37.89 ± 0.18^{ab}	39.34 ± 0.64^{a}	36.03 ± 1.92^{abc}	36.16 ± 1.92^{abc}
C18:2 *cis*, *cis*-9,12	33.08 ± 0.50^{bc}	38.02 ± 0.21^{ab}	35.49 ± 1.39^{ab}	36.54 ± 2.29^{ab}	36.34 ± 0.37^{ab}	36.67 ± 0.59^{ab}
C20:0	0.44 ± 0.08^{b}	0.19 ± 0.02^{b}	0.22 ± 0.06^{b}	0.21 ± 0.04^{b}	0.25 ± 0.02^{b}	0.21 ± 0.03^{b}
C18:3 all *cis*-9,12,15	1.37 ± 0.13^{b}	0.17 ± 0.01^{c}	1.42 ± 0.21^{b}	1.32 ± 0.17^{b}	1.16 ± 0.15^{b}	1.28 ± 0.15^{b}
C20:2 *cis*, *cis*-11,14	0.18 ± 0.06	ND	0.29 ± 0.04	ND	0.14 ± 0.01	0.07 ± 0.01
C22:0	0.16 ± 0.01^{c}	0.13 ± 0.02^{c}	0.25 ± 0.09^{c}	0.11 ± 0.04^{c}	0.08 ± 0.05^{c}	0.09 ± 0.05^{c}
C22:1 *cis*-13	0.19 ± 0.08	ND	0.17 ± 0.01	0.23 ± 0.03	0.16 ± 0.04	0.18 ± 0.01
C24:0	0.26 ± 0.02^{b}	0.17 ± 0.02^{b}	0.20 ± 0.03^{b}	0.17 ± 0.09^{b}	0.22 ± 0.01^{b}	0.26 ± 0.07^{b}
C24:1 *cis*-15	0.06 ± 0.01^{c}	0.10 ± 0.01^{bc}	0.12 ± 0.01^{abc}	0.07 ± 0.05^{abc}	0.06 ± 0.01^{c}	0.11 ± 0.03^{abc}
Σ SFA	25.92 ± 1.43^{bcd}	22.41 ± 1.21^{d}	23.95 ± 0.99^{cd}	21.92 ± 1.50^{d}	25.59 ± 1.53^{bcd}	24.06 ± 1.54^{cd}
Σ MUFA	40.02 ± 0.73^{ab}	37.95 ± 0.10^{abc}	40.16 ± 0.70^{ab}	41.49 ± 0.81^{a}	37.83 ± 2.03^{abc}	39.16 ± 2.32^{a}
Σ PUFA	33.26 ± 0.44^{bc}	38.23 ± 0.33^{ab}	35.78 ± 1.17^{ab}	36.54 ± 2.29^{ab}	36.48 ± 0.37^{ab}	36.74 ± 0.59^{ab}

$n = 3$; ND – not detected; values are expressed as mean ± standard deviations (SD); mean values with different superscript letters in the same row were significantly different ($P > 0.05$); SFA – saturated fatty acids; MUFA – monounsaturated fatty acid; PUFA – polyunsaturated fatty acid

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group. The quality and the purpose of oil are influenced by the ratio of oleic acid and linoleic acid. Naked oats also contained 0.9–4.6% of stearic acid.

There are noticeable differences in the fatty acid composition of naked oats in Table 4 and hulled oats, including their hulls and dehulled oat grains, as seen in Table 3. Generally speaking, naked oats have lower levels of palmitic and α-linolenic acids and higher levels of oleic and linoleic acids than other types of hulled oats. While dehulled Korok grain had the highest percentage of linoleic acid (38.2%), dehulled Atego grain had the highest quantity of palmitic acid. Additionally, Kamil had the highest level of stearic acid (4.6%), and Patrik had the highest amount of oleic acid (39.3%) in naked oats. Surprisingly, dehulled Atego grains had around half as much MUFAs (22%), while the number of PUFAs rose to 47.8%. In comparison to the naked, hulled, and dehulled oat grains, the oat hulls contained the most SFAs. The percentage of SFAs in Atego and Korok hulls was over 31%. Out of all the samples examined, the Patrik variety had the fewest SFAs. Lastly, naked oats showed unsaturated/saturated ratios ranging from 2.9 to 3.6, while Atego and Korok hulls had ratios of just 2.2 and 2.0, respectively.

18 varieties of whole oat grains were examined by Martinez et al. (2010) in a semi-arid setting. They discovered that the grains contained 23.2% palmitic acid, 2.3% stearic acid, 42.8% oleic acid, and 24.9% linoleic acid. Higher levels of linoleic acid and lower levels of oleic acid were found in the current investigation. In line with earlier studies (Pokhrel et al. 2022), which indicated a range of 1.21 to 2.24, the PUFAs/SFAs ratio in oats, including dehulled oats, ranged from 1.3 to 1.7. On the other hand, the ratio for hulled oats was less than 1. Among cereals, naked oats are notable for having a greater proportion of UFAs (Biel et al. 2014).

Furthermore, oats had higher UFA at 80.12%, similar to rye at 81.46% (Kan 2015). It is worth noting that, under low temperatures, oleic, linoleic, and eicosenoic acids increased, while myristic, palmitic, and palmitoleic acids decreased (Saastamoinen et al. 1990). Oats accumulate oil in the endosperm, unlike maize which stores it in the embryo. The FA profile of oats is more affected by environmental conditions than genetics (Ben Halima et al. 2015), thus the growing environment significantly impacts their composition.

CONCLUSION

In comparison to naked oats, the study examined the lipid content and FA compositions of hulled, dehulled, and hulled oat grain. The lipid content of naked oats was higher than that of hulled oats. Hulled oats had a lower lipid content than naked oats, and after the hull was removed, the lipid content of the dehulled oat grains was similar to that of naked oats. In a similar vein, oat hulls had a significantly lower lipid content. In terms of the FA profile, oleic acid was the most prevalent acid in naked oats. The distribution of FAs in naked oats and dehulled oat grain was comparable. Additionally, oat hulls have high concentrations of stearic and palmitic acids, which raised the SFA content. Hulls had lower PUFA levels than naked oats, dehulled oat grains, and hulled oats. As seen in the instance of dehulled Atego grain, where there was an increase in palmitic acid and a decrease in oleic acid, leading to greater PUFAs and lower MUFAs proportions, the removal of hulls had a noticeable effect on FA composition. Similarly, in Korok, hull removal enhanced linoleic acid while decreasing oleic, palmitic, and stearic acid proportions.

REFERENCES

Adewole D., MacIsaac J., Fraser G., Rathgeber B. (2020): Effect of oat hulls incorporated in the diet or fed as free choice on growth performance, carcass yield, gut morphology and digesta short chain fatty acids of broiler chickens. Sustainability, 12: 3744.

Ahmad A., Anjum F.M., Zahoor T., Nawaz H., Ahmed Z. (2010): Extraction and characterisation of β-d-glucan from oat for industrial utilisation. International Journal of Biological Macromolecules, 46: 304–309.

Banas A., Debski H., Banas W., Heneen W.K., Dahlqvist A., Bafor M., Gummeson P.O., Marttila S., Ekman Å., Carlsson A.S., Stymne S. (2007): Lipids in grain tissues of oat (*Avena sativa*): Differences in content, time of deposition, and fatty acid composition. Journal of Experimental Botany, 58: 2463–2470.

Batalova G.A., Krasilnikov V.N., Popov V.S., Safonova E.E. (2019): Characteristics of the fatty acid composition of naked oats of Russian selection. IOP Conference Series: Earth and Environmental Science, 337: e012039.

Ben Halima N., Ben Saad R., Khemakhem B., Fendri I., Abdelkafi S. (2015): Oat (*Avena sativa* L.): Oil and nutriment compounds valorisation for potential use in industrial applications. Journal of Oleo Science, 64: 915–932.

Biel W., Jacyno E., Kawęcka M. (2014): Chemical composition of hulled, dehulled and naked oat grains. South African Journal of Animal Science, 44: 189.

Boeck T., D'Amico S., Zechner E., Jaeger H., Schoenlechner R. (2018): Nutritional properties of various oat and naked oat

https://doi.org/10.17221/172/2024-CJFS

cultivars. Die Bodenkultur: Journal of Land Management, Food and Environment, 69: 215–226.

Bryngelsson S., Mannerstedt-Fogelfors B., Kamal-Eldin A., Andersson R., Dimberg L.H. (2002): Lipids and antioxidants in groats and hulls of Swedish oats (*Avena sativa* L). Journal of the Science of Food and Agriculture, 82: 606–614.

Capouchova I., Kourimska L., Pazderů K., Skvorova, P., Bozik M., Konvalina P., Dvořák P., Dvořáček V. (2021): Fatty acid profile of new oat cultivars grown via organic and conventional farming. Journal of Cereal Science, 98: 103180.

Decker E.A., Rose D.J., Stewart D. (2014): Processing of oats and the impact of processing operations on nutrition and health benefits. British Journal of Nutrition, 112: 58–64.

Den Besten G., Van Eunen K., Groen A.K., Venema K., Reijngoud D.J., Bakker B.M. (2013): The role of short-chain fatty acids in the interplay between diet, gut microbiota, and host energy metabolism. Journal of Lipid Research, 54: 2325–2340.

Flander L., Salmenkallio-Marttila M., Suortti T., Autio K. (2007): Optimisation of ingredients and baking process for improved wholemeal oat bread quality. LWT – Food Science and Technology, 40: 860–870.

Girardet N., Webster F.H. (2011): Oat milling: Specifications, storage, and processing. Chapter 14. In: Oats: Chemistry and Technology. 2nd Ed., Guelph, American Association of Cereal Chemists, Inc. (AACC): 301–319.

Hackett R. (2018): A comparison of husked and naked oats under Irish conditions. Irish Journal of Agricultural and Food Research, 57: 1–8.

Jawad M., Schoop R., Suter A., Klein P., Eccles R. (2013): Perfil de eficacia y seguridad de Echinacea purpurea en la prevención de episodios de resfriado común: Estudio clínico aleatorizado, doble ciego y controlado con placebo. Revista de Fitoterapia, 13: 125–135. (in Spanish)

Kan A. (2015): Characterisation of the fatty acid and mineral compositions of selected cereal cultivars from Turkey. Records of Natural Products, 9: 124–134.

Kourimska L., Sabolova M., Horcicka P., Rys S., Bozik M. (2018): Lipid content, fatty acid profile, and nutritional value of new oat cultivars. Journal of Cereal Science, 84: 44–48.

Kourimska L., Pokhrel K., Bozik M., Tilami S.K., Horcicka P. (2021): Fat content and fatty acid profiles of recently registered varieties of naked and hulled oats with and without husks. Journal of Cereal Science, 99: 103216.

Krasilnikov V.N., Batalova G.A., Popov V.S., Sergeyeva S.S. (2018): Fatty acid composition of lipids in naked oat grain of domestic varieties. Russian Agricultural Sciences, 44: 406–408.

Liu K.S. (2011): Comparison of lipid content and fatty acid composition and their distribution within seeds of 5 small grain species. Journal of Food Science, 76: 334–342.

Martinez M.F., Arelovich H.M., Wehrhahne, L.N. (2010): Grain yield, nutrient content and lipid profile of oat genotypes grown in a semiarid environment. Field Crops Research, 116: 92–100.

Menon R., Gonzalez T., Ferruzzi M., Jackson E., Winderl D., Watson J. (2016): Oats from farm to fork. Advances in Food and Nutrition Research 1: 1–55.

Ndou S.P., Tun H.M., Kiarie E., Walsh M.C., Khafipour E., Nyachoti C.M. (2018): Dietary supplementation with flaxseed meal and oat hulls modulates intestinal histomorphometric characteristics, digesta- and mucosa-associated microbiota in pigs. Scientific Reports, 8: 1–15.

Oliveira J.P., Bruni G.P., Lima K.O., El Halal S.L.M., da Rosa G.S., Dias A.R.G., da Rosa Zavareze E. (2017): Cellulose fibres extracted from rice and oat husks and their application in hydrogel. Food Chemistry, 221: 153–160.

Pokhrel K., Kourimska L., Pazderu K., Capouchova I., Bozik M. (2022): Lipid content and fatty acid profile of various European and Canadian hulled and naked oat genotypes. Journal of Cereal Science, 108: 103580.

Saastamoinen M., Kumpulainen J., Nummela S., Häkkinen U. (1990): Effect of temperature on oil content and fatty acid composition of oat grains. Acta Agriculture Scandinavica, 40: 349–356.

Sahasrabudhe M.R. (1979): Lipid composition of oats (*Avena sativa* L.). Journal of the American Oil Chemists' Society, 56: 80–84.

Schmitz E., Nordberg Karlsson E., Adlercreutz P. (2020): Warming weather changes the chemical composition of oat hulls. Plant Biology, 22: 1086–1091.

Shahbandeh M. (2023): Oats production worldwide from 2015/2016 to 2022/2023 (in million metric tons). Statistica. Available at https://www.statista.com/statistics/1073536/production-of-oats-worldwide/ (accessed Mar 5, 2024)

Welch R.W., Hayward M.V., Jones D.I.H. (1983): The composition of oat husk and its variation due to genetic and other factors. Journal of the Science of Food and Agriculture, 34: 417–426.

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