LIGNANS IN OAT AND BARLEY GRAINS DEPENDING ON GENOTYPE AND FARMING PRACTICE

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Cereals are an important source of vitamins, minerals, dietary fibre, and various phytochemicals, such as plant lignans. Lignans are a group of phenolic compounds that are commonly found in plants as their secondary metabolites. Lignans, found also in foodstuffs such as grains and seeds, are biologically active antioxidants, which reduce the occurrence of diabetes and cardiovascular diseases and prevent the progression of breast and prostate cancer. The aim of the study was to determine concentrations of lignans in different barley and oat genotypes grown under organic and conventional farming practices. Samples were collected in 2013 and 2014. The concentration of lignans was determined by high-performance liquid chromatography coupled with tandem mass spectrometry (HPLC-MS/MS). The highest concentration of total lignans was found in oat grains: 507.1 ± 3.0 (509.2 in 2013 and 505.0 in 2014) $\mu\text{g} \cdot 100^{-1} \text{g}$. In barley grains, total lignin concentration was 425.2 ± 30.3 (403.8 in 2013 and 446.6 in 2014) $\mu\text{g} \cdot 100^{-1} \text{g}$ were detected. Concentration of some lignans, like HO-Mata, Lari and Pino, was higher both in oat (450.0 , 3323 and $1159.8 \mu\text{g} \cdot \text{kg}^{-1}$, respectively) and barley grain (334.3 , 3297 and $334.4 \mu\text{g} \cdot \text{kg}^{-1}$, respectively). The lignan concentration in studied oat and barley samples did not differ significantly depending on cultivation practice.

Key words: *Avena sativa L., Hordeum vulgare L., Seco, HO-Mata, Lari, Pino, Mata, HPLC-MS/MS.*

INTRODUCTION

Phytoestrogens are biologically active compounds that naturally occur in a variety of plants, which may form part of the human diet. Structurally similar to 17β -estradiol (endogenous estrogens), they are diphenolic compounds, divided into several subclasses, including lignans and isoflavones (Grace *et al.*, 2003a; Kuijsten *et al.*, 2005; Idehen *et al.*, 2017). Phytoestrogens are receiving increasing attention due to potential protective effect against a wide range of human health problems, including breast, prostate, bowel, and other cancers, cardiovascular diseases, brain function, osteoporosis, and menopausal symptoms (Valentin-Blasini *et al.*, 2000; Grace *et al.*, 2003a; 2003b; Peterson *et al.*, 2010; Soleymani *et al.*, 2020).

Lignans are phenolic compounds found in plants, and some are converted to mammalian lignans in humans. They are

found in all cereals and especially in whole grain and bran products, since they are concentrated in the outer layers of the grain (Smeds *et al.*, 2007).

Lignans contain a diphenolic ring system based around a 2,3-disubstituted dibenzylbutane backbone. Lignans occur in foods as aglycones or as mono- and diglycosides (Grace *et al.*, 2003b). Lignans are biologically active antioxidants that have been shown to reduce the occurrence of diabetes and cardiovascular disease, and prevent the progression of breast and prostate cancer when used in animal models. Lignans can be used as food supplements in pharmaceutical and nutritional applications due to their protective role in disease prevention (Popova *et al.*, 2009). Lignans are found in foodstuffs such as grains and seeds. In the Western hemisphere most of the lignans consumed derive from whole-grain cereals, legumes, other vegetables, some fruits and

berries, olive oil, wines, tea, and coffee (Kuijsten *et al.*, 2005; Adlercreutz, 2007).

In a recent review (Zalešak *et al.*, 2019), the authors found ~300 peer-reviewed articles about studies on lignan and neolignane conducted between 2016 and mid 2018. They categorised 413 novel compounds and summarised their biological activity by chemical structure. Also, the previously described compounds were discussed.

After ingestion, plant lignans are converted by human intestinal bacteria to enterodiol (End) and enterolactone (Enl), known as mammalian lignans. End and Enl have been described as the major lignans present in serum, urine, bile, and seminal fluids of animals, including humans (Grace *et al.*, 2003a; Kuijsten *et al.*, 2005; Krajčová *et al.*, 2009).

Due to different consumption patterns and variation in microflora, plasma concentrations of End and Enl vary widely between persons. For example, Kilkkinen *et al.* (2001) reported Enl concentrations between 0 and 100 nmol·l⁻¹ in men (n = 1168) and 0 and 180 nmol·l⁻¹ in women (n = 1212). Another study (Adlercreutz *et al.* 1993), found higher concentrations in vegetarians — up to 1000 nmol·l⁻¹, n = 14.

End and Enl are also called enterolignans. They have demonstrated antioxidant and weak (anti-) estrogenic effects (Kuijsten *et al.*, 2005).

The aim of the study was to determine concentrations of lignans in barley and oat samples, depending on genotype and cultivation practice.

MATERIALS AND METHODS

All experiments were carried out from 2013 to 2014 at the Institute of Agricultural Resources and Economics (AREI) Stende Research Centre (Latvia). Spring barley (*Hordeum vulgare* L.) and oat (*Avena sativa* L.) genotypes (varieties and breeding lines) created in AREI were cultivated under two conditions — organically and conventionally (Table 1).

Organic field. The soil type was sod-podzolic sandy loam (Eutric Abeluvisols). Organic matter content was 21.6–22.3 g·kg⁻¹, pH_{KCl} 5.70–6.10, and concentration of plant-available phosphorus (P₂O₅) 138–153 mg·kg⁻¹ and potassium (K₂O) – 142–170 mg·kg⁻¹. Common agronomic practices for organic management were used during the vegetation period.

Conventional field. The soil type was sod-podzolic sandy loam (Eutric Abeluvisols). Organic matter content was 20.4–21.5 g·kg⁻¹, pH_{KCl} 5.4–5.9, available phosphorus (P₂O₅) concentration was 140.0–170.8 mg·kg⁻¹ and potassium (K₂O) – 185.3–205.0 mg·kg⁻¹. The experimental treatment consisted of three N rates (N80, N120, and N160) in conventional growing conditions. Complex mineral fertiliser was used as a basic fertiliser at the rate 725 kg·ha⁻¹ (N – 80 kg·ha⁻¹, P – 28.6, and K – 112.4 kg·ha⁻¹). The N applica-

Table 1. Evaluated barley and oat genotypes

Genotype	Origin	Description
Barley		
1185	Simba/Wanubet	hulless barley breeding line
Kornelija	SCBN852.7/Sauce/3/Mola/Schuri//Arupo*2/Jet	naked barley variety (breeding line IC 360)
1165	Gainer/Freedom	naked barley breeding line
Ansis	KM246-3.78/Taifun	widely grown malting barley variety
Oats		
Stendes Emilija	Selma/NosNacht	naked oat variety (breeding line S-156)
33793	Nosnacht/Stmara	naked oat breeding line
Lizete	Dzintara//Sovetskij/Premis/3/STL1986	new hulled oat variety

tion was split with part of the N being applied at the time of sowing and the remaining half at the end of tillering stage (growing stage/GS 29) of the crop. Ammonium nitrate (N 34%) was used as a top-fertiliser in the following amounts: 40 kg N·ha⁻¹ (N120) and 80 kg N·ha⁻¹ (N160). The treatments were laid out in a randomised complete block design; the plot size was 10 m², four replicates.

Weather conditions. Average daily temperature in 2013 and 2014 exceeded the long-term average or norm by 0.6 to 3.5 °C in May and in July. Dry conditions in both years of the study occurred in July (41.6% of the norm in 2013 and 59% in 2014). Differences among years were observed in the average daily temperature in June — temperature above norm in 2013, and below norm in 2014; this month in both years was rich with precipitation (130% of the long term average in 2013 and 174.9% in 2014).

Sample preparation. Sampling was done according to ISO 950 Cereals-Sampling (as grain). Approximately 200 mg of whole-grain flour was treated with 5.0 ml 70% methanol containing 0.3 M NaOH for 1 h at 60 °C. After incubation, the samples were cooled to room temperature and centrifuged for 10 min at 10 °C and 4500 rpm in order to precipitate salts. The supernatant was transferred to a fresh tube and the extraction was repeated. The supernatants were pooled, pH was adjusted to 5–6 using glacial acetic acid (~90 µl) and the samples were centrifuged. An aliquot of 8.5 ml of this solution was withdrawn for enzymatic hydrolysis (Kuijsten *et al.*, 2005; Krajčová *et al.*, 2009). An aliquot was evaporated under N₂ stream (60 °C).

Enzymatic hydrolysis. 170 µl of enzyme solution (1 ml of original enzyme was dissolved in 10 ml of Na-acetate buffer getting concentration 13600 U/ml; the necessary 2300 Units per sample correspond to ~170 µl of this enzyme diluted in buffer) was added. Then, an additional amount of buffer (0.05 M Na-acetate buffer, pH 5) was added per sample to achieve 3 ml. The mixture was incubated for 19 hours at 37 °C in a drying cabinet. Then, the mixture was cooled to room temperature and extracted with diethylether (2 × 2.0 ml). The supernatants were pooled and evaporated to dry-

Table 2. Lignan compound concentration in oat in 2013 and 2014, $\mu\text{g}\cdot\text{kg}^{-1}$ (mean $\pm$ SD, $n = 24$)

Genotype	Seco	HO-Mata	Lari	Pino	Mata
33793+80	n/a	377.7 ± 18.0	3318.0 ± 46.7	914.0 ± 104.7	125.6 ± 79.8
33793+120	n/a ¹⁾	376.3 ± 14.7	3327.5 ± 60.1	831.0 ± 2.8	109.8 ± 57.5
33793+160	n/a	370.0 ± 0.6	3342.5 ± 55.9	1022.5 ± 170.4	156.1 ± 84.6
33793+Bio	$9.0 \pm 12.7^{2)}$	381.3 ± 1.3	3344.0 ± 32.5	1014.5 ± 77.1	126.8 ± 36.7
Lizete+80	n/a	572.5 ± 104.6	3304.0 ± 41.0	914.0 ± 49.5	136.9 ± 9.6
Lizete+120	n/a	620.7 ± 196.0	3345.5 ± 77.1	860.0 ± 213.6	148.2 ± 35.1
Lizete+160	n/a	706.4 ± 285.0	3290.5 ± 85.6	900.5 ± 118.1	177.5 ± 16.0
Lizete+Bio	$42.2 \pm 59.7^{3)}$	502.6 ± 75.9	3342.5 ± 60.1	1226.0 ± 342.2	143.7 ± 31.9
Stendes Emilija+80	$19.1 \pm 27.0^{2)}$	380.8 ± 12.2	3284.5 ± 21.9	1543.5 ± 375.5	112.0 ± 0
Stendes Emilija+120	$4.0 \pm 5.7^{3)}$	379.0 ± 0.6	3351.0 ± 0.0	1480.0 ± 82.0	118.9 ± 12.8
Stendes Emilija+160	n/a	370.9 ± 3.2	3309.0 ± 8.5	1545.5 ± 33.2	108.7 ± 17.6
Stendes Emilija+Bio	$15.5 \pm 21.9^{2)}$	361.4 ± 2.6	3310.5 ± 14.9	1665.5 ± 229.8	113.2 ± 14.4
Mean, all	7.5	450.0	3323	1159.8	131.5
Mean, 33793	2.3	376.3	3333	945.5	129.6
Mean, Lizete	10.5	600.6	3321	975.1	151.6
Mean, Stendes Emilija	9.7	373.0	3314	1558.6	113.2
Mean, conventional	2.6	461.6	3319	1112.3	132.6
Mean, organic	22.2	415.1	3332	1302.0	127.9

SD, standart deviation; ¹⁾ n/a – not available (5.0); ²⁾ only in 2013, in 2014 – n/a; ³⁾ only in 2014, in 2013 – n/a.

ness. Dry residue was dissolved in a solution of acetonitrile with 0.1% glacial acetic acid/H₂O (1:1), filtered through 0.2 μm filters. This solution was then used for HPLC-MS/MS analysis. Some evaporated samples were stored for seven days in a freezer at $-21\text{ }^{\circ}\text{C}$.

The following lignans were analysed: Seco (secoisolariciresinol), HO-Mata (7- hydroxymatairesinol), Lari (lariciresinol), Pino (pinoresinol), and Mata (matairesinol).

Data analysis. The software package IBM Corp. Released 2013, IBM SPSS Statistics for Windows, version 22.0, was used for data statistical analysis. For data analysis, the following methods were used: descriptive statistics: mean, standard deviation and inferential statistics Mann–Whitney test, Kruskal–Wallis test, t-test.

The following coding system was used to describe genotype and farming practices: ‘1185’+BIO – barley genotype grown organically; ‘1185’+120 – barley genotype grown conventionally with N supply $120\text{ kg}\cdot\text{ha}^{-1}$.

RESULTS

Oat grain. The concentration of Seco was low in all samples and in many cases it was under the detection limit (Table 2). The highest HO-Mata concentration was in ‘Lizete + 160’ ($706.4\text{ }\mu\text{g}\cdot\text{kg}^{-1}$). The Lari concentration was similar in all analysed oat genotypes; the highest occurred in ‘Stendes Emilija’+120 ($3351.0\text{ }\mu\text{g}\cdot\text{kg}^{-1}$). The highest Pino concentration was in ‘Stendes Emilija’+Bio ($1665.5\text{ }\mu\text{g}\cdot\text{kg}^{-1}$), and the highest Mata concentration in ‘Lizete+160’ ($177.5\text{ }\mu\text{g}\cdot\text{kg}^{-1}$) (Table 2).

The highest total lignan concentration was observed in all variants of ‘Stendes Emilija’ ($533.3\text{--}546.4\text{ }\mu\text{g}\cdot 100\text{ g}^{-1}$), and

the lowest concentration in ‘33793’+120 ($464.5\text{ }\mu\text{g}\cdot 100\text{ g}^{-1}$) (Table 3). The lignan concentrations in oat genotypes are presented in Table 3.

In 2014, the total lignan concentration in oat genotypes was slightly lower than in 2013 (average lignan concentration in 2013 was $509.2\text{ }\mu\text{g}\cdot 100\text{ g}^{-1}$, in 2014 — $505.0\text{ }\mu\text{g}\cdot 100\text{ g}^{-1}$), the difference was not statistically significant (*t*-test, $p = 0.701$).

The total lignan concentration in oat genotypes did not differ significantly between organic or conventional (N80, N120, N160) growing conditions (Kruskal–Wallis test, $p = 0.193$), and depending on agricultural practice (*t*-test, $p = 0.598$).

Barley grain. The highest Seco concentration was in variants ‘1165+Bio’ ($253.9\text{ }\mu\text{g}\cdot\text{kg}^{-1}$) and ‘Kornelija’+80 ($250.7\text{ }\mu\text{g}\cdot\text{kg}^{-1}$); the variation of Seco concentration was high for all variants. The highest HO-Mata concentration was in ‘Ansis+Bio’ ($401.6\text{ }\mu\text{g}\cdot\text{kg}^{-1}$). The Lari concentration was similar in all analysed barley genotypes; the highest oc-

Table 3. Lignan concentration in oat in 2013 and 2014, $\mu\text{g}\cdot 100\text{ g}^{-1}$ ($n = 24$)

Genotype	2013	2014	Mean $\pm$ SD
Stendes Emilija+80	564.9	503.1	534.0 ± 43.7
Stendes Emilija+120	537.7	528.8	533.3 ± 6.3
Stendes Emilija+160	537.8	529.0	533.4 ± 6.3
Stendes Emilija+Bio	564.6	528.7	546.6 ± 25.4
Mean, all genotypes	509.2	505.0	507.1 ± 3.0
Mean, 33793	472.1	485.2	478.7 ± 9.3
Mean, Lizete	504.3	507.3	505.8 ± 2.1
Mean, Stendes Emilija	551.2	522.4	563.8 ± 20.4
Mean, conventional	506.5	499.1	502.8 ± 5.2
Mean, organic	517.3	522.6	519.9 ± 3.7

Table 4. Lignan compound concentration in barley in 2013 and 2014, $\mu\text{g}\cdot\text{kg}^{-1}$ (mean $\pm$ SD, n = 32)

Genotype	Seco	HO-Mata	Lari	Pino	Mata
1165+80	154.1 $\pm$ 172.1	372.7 $\pm$ 32.5	3270.5 $\pm$ 14.9	451.0 $\pm$ 63.0	134.6 $\pm$ 44.7
1165+120	175.4 $\pm$ 248.1	348.4 $\pm$ 4.5	3258.5 $\pm$ 14.9	286.4 $\pm$ 32.9	117.7 $\pm$ 17.5
1165+160	98.0 $\pm$ 115.1	362.8 $\pm$ 26.2	3268.0 $\pm$ 32.5	286.3 $\pm$ 93.2	238.5 $\pm$ 86.2
1165+Bio	253.9 $\pm$ 359.1	342.1 $\pm$ 0.6	3251.0 $\pm$ 38.2	286.3 $\pm$ 82.2	135.8 $\pm$ 84.6
1185+80	122.4 $\pm$ 166.0	344.3 $\pm$ 5.1	3297.0 $\pm$ 12.7	356.1 $\pm$ 175.3	133.5 $\pm$ 39.9
1185+120	102.3 $\pm$ 117.2	278.5 $\pm$ 252.4	3291.0 $\pm$ 65.0	241.8 $\pm$ 74.0	88.3 $\pm$ 11.2
1185+160	124.6 $\pm$ 165.0	174.0 $\pm$ 246.1	3272.5 $\pm$ 17.7	257.3 $\pm$ 63.0	130.7 $\pm$ 23.1
1185+Bio	140.1 $\pm$ 198.2	358.3 $\pm$ 13.4	3278.5 $\pm$ 47.4	290.2 $\pm$ 76.7	108.7 $\pm$ 30.3
Ansis+80	157.8 $\pm$ 114.1	363.7 $\pm$ 4.5	3312.0 $\pm$ 12.7	313.5 $\pm$ 158.9	96.3 $\pm$ 28.8
Ansis+120	72.0 $\pm$ 41.7	375.9 $\pm$ 37.0	3359.0 $\pm$ 91.9	385.2 $\pm$ 216.5	113.2 $\pm$ 49.5
Ansis+160	123.2 $\pm$ 87.6	375.8 $\pm$ 1.3	3421.0 $\pm$ 132.9	385.1 $\pm$ 79.5	124.5 $\pm$ 49.5
Ansis+Bio	163.1 $\pm$ 230.6	401.6 $\pm$ 17.2	3301.5 $\pm$ 88.4	422.0 $\pm$ 137.0	117.7 $\pm$ 11.2
Kornelija+80	250.7 $\pm$ 235.3	354.7 $\pm$ 1.9	3302.5 $\pm$ 51.6	344.4 $\pm$ 65.8	101.9 $\pm$ 46.3
Kornelija+120	222.5 $\pm$ 262.8	352.4 $\pm$ 11.5	3296.5 $\pm$ 64.4	340.6 $\pm$ 126.1	103.0 $\pm$ 28.7
Kornelija+160	207.8 $\pm$ 293.8	178.5 $\pm$ 252.4	3296.5 $\pm$ 47.4	352.2 $\pm$ 93.1	110.9 $\pm$ 59.1
Kornelija+Bio	234.8 $\pm$ 206.8	178.5 $\pm$ 26.8	3275.5 $\pm$ 13.4	352.2 $\pm$ 115.1	121.1 $\pm$ 41.5
Mean all	162.7	334.3	3297	334.4	123.5
Mean 1165	170.4	356.5	3262	327.5	156.7
Mean 1185	122.4	288.8	3285	286.4	115.3
Mean Ansis	129.0	379.3	3348	376.5	112.9
Mean Kornelija	229.0	312.7	3293	347.4	109.2
Mean conventional	150.9	323.5	3304	333.3	124.4
Mean organic	198.0	366.8	3277	337.7	120.8

SD, standart deviation

curred in ‘Ansis+160’ (3421 $\mu\text{g}\cdot\text{kg}^{-1}$). The highest Pino concentration was in ‘1165+80’ (451.0 $\mu\text{g}\cdot\text{kg}^{-1}$), and the highest Mata concentration in ‘1165’+160 (238.5 $\mu\text{g}\cdot\text{kg}^{-1}$) (Table 4).

The highest total lignan concentration was in ‘Ansis’+160 (mean 443.0 $\mu\text{g}\cdot 100\text{ g}^{-1}$), and the lowest concentration in ‘1185’ + 160 (395.9 $\mu\text{g}\cdot 100\text{ g}^{-1}$). The lignan concentrations in barley genotypes in 2013 and 2014 are presented in Table 5.

In 2014, compared with 2013, the lignan concentration in barley genotypes was higher (see Table 5). The lignan concentration differed statistically significantly in barley genotypes between 2013 and 2014 (Mann–Whitney test, $p < 0.001$). The lignan concentration in barley genotypes did not differ significantly depending on organic or conventional (N80, N120, N160) growing conditions (Kruskal–Wallis test, $p = 0.842$), and depending on agricultural practice (t-test, $p = 0.472$).

DISCUSSION

The aim of our study was to determine the concentration of lignan compounds in oats and barley, the most popular cereals cultivated in Latvia and with high potential as ingredients of healthy food products. We also tested the effects of genotypes of Latvian origin, farming practices (organic and

Table 5. Lignan concentration (LC) in barley in growing years 2013 and 2014, (mean $\pm$ SD, n = 32)

Genotype	2013	2014	Mean $\pm$ SD
1165+80	415.2	461.1	438.3 $\pm$ 32.7
1165+120	396.2	441.1	418.6 $\pm$ 31.8
1165+160	412.6	438.1	425.4 $\pm$ 18.1
1165+Bio	387.1	466.7	426.9 $\pm$ 56.3
1185+80	397.8	452.8	425.3 $\pm$ 38.9
1185+120	382.8	417.6	400.2 $\pm$ 24.6
1185+160	362.8	429.0	395.9 $\pm$ 46.9
1185+Bio	391.7	443.4	417.6 $\pm$ 36.6
Ansis+80	430.1	418.5	442.3 $\pm$ 8.2
Ansis+120	442.5	418.6	435.0 $\pm$ 16.9
Ansis+160	436.6	449.3	443.0 $\pm$ 9.0
Ansis+Bio	428.1	453.0	440.6 $\pm$ 17.6
Kornelija+80	407.1	463.8	435.4 $\pm$ 40.1
Kornelija+120	401.6	461.4	431.5 $\pm$ 42.3
Kornelija+160	361.8	467.3	414.6 $\pm$ 74.6
Kornelija+Bio	406.3	463.4	434.9 $\pm$ 40.3
Mean all	403.8	446.6	425.2 $\pm$ 30.3
Mean 1165	402.7	451.8	427.3 $\pm$ 34.7
Mean 1185	383.8	435.7	409.7 $\pm$ 36.7
Mean Ansis	434.3	434.9	434.6 $\pm$ 0.4
Mean Kornelija	394.2	464.0	429.1 $\pm$ 49.3
Mean conventional	403.9	443.2	423.6 $\pm$ 27.8
Mean organic	403.3	456.6	430.0 $\pm$ 37.7

conventional) and cultivation years on variation of concentration of several lignans.

According to obtained data (see Tables 2 to 5), Lari was the main component of total lignan content (TLC) of oat (65%) and barley (78%). Other lignans in oats are Pino (23%), HO-Mata (9%) and Mata (3%). Proportion of Seco content was only 0.15%. In barley the content of HO-Mata and Pino was 8% each and of Seco — 4% and Mata — 3%.

Our results were compared with data from different literature sources (Table 6).

In samples from Italy (Durazzo *et al.*, 2009; 2013) the composition of lignans differed: in oat grain the concentration of Pino was three times higher, and the concentration of Lari ~3 times lower than in Latvian oat samples. Mata was not identified in Italian oat and barley samples. Total lignan content was about 80% and 50% of the TLC in Latvian oat and barley samples, respectively.

In oat samples from the local Finland market (Peñalvo *et al.*, 2005; Peterson *et al.*, 2010) the TLC was similar to that of Latvian samples (in samples from Finland HO-Mata was not analysed, while syringaresinol (Syr) concentration was 352 $\mu\text{g}\cdot 100\text{ g}^{-1}$ and medioresinol (Med) — 40 $\mu\text{g}\cdot 100\text{ g}^{-1}$, which were not analysed in Latvian samples.

The concentration of Lari was lower in the samples from Finland, and the concentration of Seco, Pino, and Mata were higher.

The analysis of 55 oat samples from five genotypes in Finland (Smeds *et al.*, 2009) in most cases showed noticeably higher lignin concentration, in comparison with Latvian samples.

High concentration of lignans was found in oat bran from Finland (Smeds *et al.*, 2007) and in barley bran (Smeds *et al.*, 2007; Idehen *et al.*, 2017). This can explain the lower concentration of lignans in dehulled grain or naked grain genotypes.

Dutch and Finnish (Fineli[®]) databases (Teten *et al.*, 2013) on oat and barley mean show noticeably lower concentration of TLC, as well as Lari, Pino, and Mata concentrations, than in our samples; only concentration of Seco was higher than in Latvian samples of oat and similar to barley samples.

In general, Lari and Pino are the main components of TLC (Table 6), while proportional contents of Seco, HO-Mata, and Mata are lower.

The concentration of lignans may vary also within the same genotype as a consequence of different growing conditions, geographical location and climate.

Overall, the obtained results on lignan concentrations provide valuable additional information for food and nutrition scientists on the composition of oat and barley grain raw material grown in Latvia, which can raise future interest in this component of grain of these cereals.

CONCLUSIONS

Total lignan concentration was higher in oat grain compared with barley — difference 81.9 $\mu\text{g}\cdot 100\text{ g}^{-1}$. Mean concentration of some lignans, like HO-Mata, Lari, and Pino, for both cereals were high, while concentration of Seco was near the detection limit. Concentration of Mata was fairly similar in oat and barley grain.

Table 6. Lignan compound concentration and total lignan content (TLC) in oat and barley grain in different investigations, $\mu\text{g}\cdot 100\text{ g}^{-1}$ dry weight

Grains	Seco	HO-Mata	Lari	Pino	Mata	TLC ¹⁾	Reference and notes
Oat,	0.75	45.0	332.3	115.9	13.2	507	This research, 24 samples of 3 genotypes
Oat	n/a	–	97	304	n/a	401	Durazzo <i>et al.</i> , 2013; Durazzo <i>et al.</i> , 2009; Italian farms, 2 genotypes
Oat	19	–	183	194	71	859 ²⁾	Peñalvo <i>et al.</i> , 2005, Peterson <i>et al.</i> , 2010, local market, Finland
Oat	6–13	–	340–599	214–683	0–104	820–2550	Smeds <i>et al.</i> , 2009, 55 samples of 5 genotypes, Finland
Oat bran	90	712	766	567	440	2575	Smeds <i>et al.</i> , 2007, local market, Finland
Oat and barley, mean	13	–	60	29	5	107	Teten <i>et al.</i> , 2013, Dutch database
Oat and barley, mean	13	–	–	–	5	18	Teten <i>et al.</i> , 2013, Finnish (Fineli [®]) database
Barley,	16.3	33.4	330	33.4	12.4	425	This research, 32 samples of 4 genotypes
Barley	28	–	132	45	n/a	206	Durazzo <i>et al.</i> , 2013; Durazzo <i>et al.</i> , 2009; Italian farms, 2 dehulled genotypes
Barley	30	–	85	72	3	359 ³⁾	Durazzo <i>et al.</i> , 2013; Peñalvo <i>et al.</i> , 2005, local market, dehulled
Barley bran	42	541	133	71	42	969 ⁴⁾	Smeds <i>et al.</i> , 2007; Idehen <i>et al.</i> , 2017

¹⁾ Sum of analysed lignans

²⁾ Included 352 $\mu\text{g}\cdot 100\text{ g}^{-1}$ syringaresinol (Syr) and 40 $\mu\text{g}\cdot 100\text{ g}^{-1}$ medioresinol (Med)

³⁾ Included 169 $\mu\text{g}\cdot 100\text{ g}^{-1}$ syringaresinol (Syr)

⁴⁾ Included 140 $\mu\text{g}\cdot 100\text{ g}^{-1}$ syringaresinol (Syr)

There were no statistically significant differences between oat genotypes, their growing conditions (conventional or organic) and year of growing (weather conditions). However, lignan concentration in grain of the naked oat variety ‘Stendes Emilija’ was higher than in covered barley genotypes — mean difference 71.6 $\mu\text{g}\cdot 100\text{ g}^{-1}$.

There was no considerable difference in total lignin concentration among investigated covered and naked barley genotypes. The total lignan concentration in barley genotypes did not differ significantly depending on organically or conventionally growing conditions. The total lignan concentration in barley genotypes was higher in 2014 in comparison with 2013, and the differences were statistically significant. This suggests that weather conditions of the growing year can influence lignin concentration of barley grains.

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LIGNĀNI AUZU UN MIEŽU GRAUDOS ATKARĪBĀ NO GENOTIPA UN LAUKSAIMNIECĪBAS PRAKSES

Graudaugi ir nozīmīgs vitamīnu, minerālvielu, diētiskās šķiedras un dažādu fitoķīmisko vielu, piemēram, augu lignānu avots. Lignāni ir fenola savienojumu grupa, tie parasti atrodas augos kā to sekundārie metabolīti. Lignāni ir atrasti arī graudos un to pārstrādes produktos. Lignāni ir bioloģiski aktīvi antioksidanti, kuri mazina diabēta, sirds un asinsvadu slimību rašanos, novērš krūts un prostatas vēža progresēšanu. Pētījuma mērķis bija noteikt lignānu daudzumu Latvijā selekcionētu miežu un auzu šķirņu un līniju graudos atkarībā no lauksaimniecības prakses. Auzas un mieži tika audzēti bioloģiski un konvencionāli. Paraugi analizēm vākti 2013. un 2014. gadā. Lignānu saturu noteica ar augstas izšķirtspējas šķidrums hromatogrāfiju ar tandēma maspektrometriju (HPLC-MS/MS). Lielākie kopējo lignānu daudzumi tika konstatēti auzu graudos: $507,1 \pm 3,0$ ($509,2$ 2013. gadā un $505,0$ 2014. gadā) $\mu\text{g} \cdot 100 \text{ g}^{-1}$. Miežu graudos $425,2 \pm 30,3$ ($403,8$ 2013. gadā un $446,6$ 2014. gadā) $\mu\text{g} \cdot 100 \text{ g}^{-1}$. Dažu lignānu, piemēram, HO-Mata, Lari un Pino, saturs bija lielāks gan auzu (attiecīgi $450,0$, 3323 un $1159,8 \mu\text{g} \cdot \text{kg}^{-1}$), gan miežu graudos (attiecīgi $334,3$, 3297 un $334,4 \mu\text{g} \cdot \text{kg}^{-1}$). Lignānu koncentrācija auzu un miežu genotipu graudos atkarībā no pielietotās lauksaimniecības prakses būtiski neatšķiras.