

EFFECT OF GENOTYPE AND ENVIRONMENTAL ON THE OIL CONTENT AND FATTY ACID COMPOSITION OF HEMPSEED

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Introduction

Today the human diet consists of an 11:1 ratio of omega-6 (linoleic acid or LA) to omega-3 (linolenic acid or LNA) fatty acids. However, a more ideal ratio, based on evolutionary and anthropological data, would be in the range of 1:1 to 4:1. In other words, our ancestors consumed a higher percentage of omega-3 fatty acids-and we probably should, too (Challem, 1997). Many authors have investigated the factors which determine the oil content and fatty acid composition of linseed. Linseed is uniquely rich in linolenic acid. (Hitchcock and Nichols, 1971; Kádár *et al.*, 2004; Izsáki, 2004; Hassan *et al.*, 2005). At low temperatures there is an increase in the proportion of unsaturated fatty acids. Warmer conditions lead to a greater accumulation of oleic acid at the expense of linoleic and linolenic acids (Hilich and Williams, 1964). Nutrient deficiencies generally have a less pronounced effect on the lipid and fatty acid composition of the seeds than on the tissues of vegetative organs of the plant. According to some studies P supplies increased the quantity of linoleic acid, N fertilization significantly reduced it. However the opposite effect has also been observed (Kádár *et al.*, 2004; Hitchcock and Nichols, 1971).

Less research has been undertaken on the effect of genetic and environmental factors on the content and fatty acid composition of hempseed oil. The hempseed oil content of the seed ranges from 29-35% depending on the variety, location and cultivation techniques. The saturated fatty acid content is about 10%, and nearly 90% of the content is unsaturated acids which have the following composition: oleic acid (18:1 w9) 8,5-1 acid (18:3 w3) 15-25 and stearidonic acid (18:4 w3) 0,4-2 %.(Deferne and Pate, 1996; Roulac, 1996; Izsáki, 1998; Scheifele and Dragla, 2001; Izsáki and Iványi, 2004; Bócsa, 2004)). The two polyunsaturated essential fatty acids, LA (C18:2w6)" and LNA (C18:3w3) usually account for approximately 50-70% and 15-25% respectively of the total hempseed fatty acid content (Theimer and Mölleken 1995, Rummyantseva and Lemeshev 1994). A 3:1 ratio of LA and LNA is considered optimal for human nutrition (Erasmus 1993). Apparently, this ratio is unique among the common plant oils.

Gamma-linolenic acid (C18:3w6) or GLA is not found in oils usually consumed by the majority of people. Hemp seed oil obtained from sterilised seed analyzed in the US contained 1.7% GLA (Weil 1993, Wirtshafter 1995), but higher levels (3-6%) have been measured by German investigators (Theimer and Mölleken 1995). Eicosanoids are short-lived hormone-like substances which fulfil numerous essential roles in humans ranging from the control of inflammation processes and vascular tone to the initiation of contractions during delivery (Horrobin, 1992).

The oil content and the composition of the fatty acids depend also on the maturity of the hemp fruits. The content of palmitic acid (C16:0) is higher in immature seeds (Mölleken *et al.* 2000). In Canada Scheifele and Dragla, 2001 demonstrated that the site effect was greater than genetic variability on the oil content of hempseed averaged across 5 varieties. The oil content for all varieties and sites in 1999 was 2,5 % higher than in 1998. The fatty acid profile of hemp oil appeared to be very consistent and stable for the 8 varieties across the 5 research sites in 1999. Hence, site environment had a greater impact on total fatty acid variability than

genetics. N fertilization had no demonstrable effect on the oil content and fatty acid profile of hempseed.

Methods

To assess the influence of the genotype on the oil content and fatty acid composition of hemp a field experiment was carried out in 2004. Ten genotypes were compared in 4 replications. The plant density at harvest was 100 plants m^{-2} in 2001 and 150 plants m^{-2} in 2004. The site effect was tested on a Finola variety cultivated in UK in 2003 (52° N 0° E latitude at 60m elevation) and cultivated Hungary in 2005 (46° 30' N, 16° 30' E latitude at 80m elevation).

The fertilization effect was investigated in the field experiment in 2001 with a China monoecious genotype in Szarvas, on chernozem meadow soil, with an 85-100 cm thick humus layer. All possible combination of 4 levels each of N, P and K were included, giving a total of 64 fertiliser treatments arranged in a split-split plot design with three replications. The fertiliser levels applied were $N_0 = 0$, $N_1 = 80$, $N_2 = 160$, $N_3 = 240$ kg N ha^{-1} year $^{-1}$ for nitrogen; $P_0 = 0$, $P_1 = 100$ kg ha^{-1} year $^{-1}$, $P_2 = 500$ kg ha^{-1} in 1989 and 1993, $P_3 = 1000$ kg ha^{-1} in 1989 and 1993 for phosphorus (P_2O_5); and $K_0 = 0$, $K_1 = 300$ kg ha^{-1} year $^{-1}$ from 1989–1992, 100 kg ha^{-1} year $^{-1}$ from 1993, $K_2 = 600$ kg ha^{-1} in 1989, 1000 kg ha^{-1} in 1993, $K_3 = 1200$ kg ha^{-1} in 1989 and 1500 kg ha^{-1} in 1993 for potassium (K_2O).

The weather in 2001, 2004 and 2005 was favourable for hempseed yield. The quantity of rainfall from April till September was higher than the annual average - 455 mm, 390 mm and 518 mm in 2001, 2004 and 2005 respectively. A chemical analysis of the mature seeds was undertaken. The oil and fatty acids content were determined by GC with internal standard method after esterification with methanol.

Results and discussion

In 2004 during the wet season the average oil content of the varieties (23,35%) was lower than recorded in the relatively dry growing season in Szarvas in 2000 (33,2%) (Izsáki-Iványi, 2004). Genetic variability ranged from 21,56 to 32,24%. Felina 34 had the highest oil content 32,24% and Kompolti was lowest with 21,74 % (Table 1).

Table 1. Oil content and fatty acid composition of hempseed varieties on different environment

Genotype effect (2004, Szarvas)										
Varieties	Oil content	Palmitic (16:0)	Stearic (18:0)	Arachidic (20:0)	Oleic (18:1 omega-9)	Eicosaenic (20:1)	LA Linoleic (18:2 omega 6)	LNA Alfa linolenic (18:3 omega 3)	GLA Gamma linolenic (18:3 omega 6)	SDA Stearidonic (18:4 omega 3)
	%	%	%	%	%	%	%	%	%	%
Felina 34	32,24	7,06	2,93	0,82	14,04	0,46	56,04	15,14	2,81	0,71
Futura 75	28,29	6,77	3,26	0,79	12,65	0,36	56,38	17,17	1,96	0,65
Fibranova	27,45	7,31	2,96	0,93	13,81	0,41	57,39	15,49	1,33	0,38
Ferimon	27,24	7,75	2,67	0,88	14,79	0,45	55,73	13,66	3,30	0,76
Dioica 88	24,43	6,76	2,84	0,80	11,62	0,39	56,78	19,07	1,27	0,47
Lovrin 110	24,28	7,79	3,18	1,00	16,60	0,42	55,17	13,81	1,63	0,41
Carmagnola	23,39	7,71	2,59	0,81	13,57	0,40	55,08	17,99	1,39	0,47
Chameleon	22,94	6,73	3,06	0,91	12,22	0,40	56,40	17,78	1,84	0,67
Fedora 14	21,74	7,72	3,00	0,91	13,09	0,04	55,86	15,44	2,78	0,77
Kompolti	21,56	7,01	3,24	0,80	12,05	0,39	55,58	19,29	1,17	0,48
Average	25,35	7,26	2,97	0,95	13,44	0,37	56,04	16,48	1,94	0,58
Environmental effect (2003 UK, 2005 Hungary)										
Finola (2003) UK	24,58	6,41	2,48	0,87	9,66	0,41	55,64	18,94	4,16	1,43
Finola (2005) Hungary	22,86	7,09	2,39	0,91	11,07	0,43	55,59	16,52	4,64	1,32

In 2004 the saturated mono- and diunsaturated fatty acids had a smaller relative range (14-30%) in genetic variability than the higher polyunsaturated fatty acids with relative differences in the region of 30-60%.

The Finola variety of hempseed oil was prominent among varieties with high LNA, GLA and SDA fatty acids content, in terms of both year and site. In Hungary in 2005, the oleic acid and GLA % content were higher than observed in the UK in 2003. The ratio of LA and LNA on average in varieties was favourable at 3,35:1 which is unique in the plant world. Finola and Dioica were prominent with 2,1:1 ratio.

In 2001 N and P fertilization did not influence significantly the oil content and fatty acid composition of the hempseed oil.

References

- Bócsa I.(2004): A kender és termesztése. (Hemp and hempcultivation) Agroinform Kiadó, Budapest. 31.p.
- Challem, J. (1997): "Did the Loss of Endogenous Ascorbate Propel the Evolution of Anthropeida and Homo sapiens?" Medical Hypotheses, 48: 387-392.

- Deferne, J.-L.- Pate, D. W. (1996): Hemp seed oil: A source of valuable essential fatty acids Journal of. International Hemp Association 3. 1. June, 1-7 p.
- Erasmus, U. (1993): Fats That Heal, Fats That Kill: The Complete Guide to Fats, Oils, Cholesterol and Human Health. Alive Books, Canada.
- Hassan, F. U.- Leitch, M. H.- Abbasi, M. K. (2005): Effects of seeding densities and row spacing on yield and yield components of linseed (*Linum usitatissimum* L.) Acta Agonomica Hungarica. 53. 3. 8. 309 - 317 pp.
- Hilditch, T. P. - Williams P. N. (1964): The chemical constitution of the natural fats. Chapman and Hall, London.
- Hitchcock, C. – Nichols, B. W. (1971): Plant lipid biochemistry. Academic Press, London – New York.
- Horrobin, D.F.(1992): Nutritional and medical importance of gamma-linolenic acid. Prog. Lipid Res. 31(2): 163-94.
- Izsáki Z. (1998): Soybean quality as affected by N, P fertilization. 2nd Balkon Symposium on Field Crops. Novi Sad, Yugoslavia, 243-246.
- Izsáki Z. (2004): Effect of nutrient supplies on the nutrient uptake, yield and quality of linseed (*Linum usitatissimum* L.) Növénytermelés, 53. 75-95.
- Izsáki Z.- Iványi I. (2004): Effect of Nutrient Supply on the Quality of Linseed and Hempseed. J. Natural Fibres 1. (4) 59-75.
- Kádár, I. - Lukács D.-né- Sándor L.-né. (2004): Fertilization effect on linseed yield, quality and nutrient uptake of linseed. Agrokémia és Talajtan 53. (1-2). 75-92. p.
- Leson, G. - Pless, P. (1999): Hemp food and oils for health. HEMPTECH, Sebastopol, California.
- Mölleken, H.- Mothe, R. - Dudek, S. (2000): Quality of hemp-fruits and hemp oil in relation to the maturity of the fruits. Bioresource Hemp, Wolfsburg, www.nova-institut.de
- Roulac, J. W. (1996): Industrial hemp. Practical products – Paper to fabric to cosmetics. HEMPTECH, Sebastopol, California.
- Rumyantseva, L.G. - Lemeshev, N.K. (1994): Current state of hemp breeding in the C.I.S. JIHA 1(2): 49-50.
- Theimer, R. R. - Mölleken, H. (1995): Analysis of the oil from different hemp cultivars - perspectives for economical utilization. Pages 536-543 in *Bioresource Hemp*, 2nd edition. nova-Institute, Rosenstr. 53, 50678 Cologne, Germany.
- Scheifele, G. - Dragla, P.(2001): Environment and genitic effect on the quality of industrial hemp grain, seed cake and oil extracted from grain grown across Northern Ontario, Canada in 1998, 1999 and 2000. Proceedings of the Bast Fibrous Plants on the Turn of Second and Third Millennium Conference, Shenyang, China, IV/14, 1-12.
- Weil, A.(1993): Therapeutic hemp oil. Natural Health, March/April, pps. 10-12.
- Wirtshafter, D.(1995): Nutrition of hemp seeds and hemp seed oil. Pages 546-555 in *Bioresource Hemp*, 2nd edition. nova-Institute, Germany.
- Kádár, I. (2004): Szennyvíziszap-adagok hatása a növény (*Triticum vulgare* L.)-talaj rendszer néhány mikrobiológiai és biokémiai tulajdonságára (Impact of sludge treatments on some microbiological and biochemical properties of plant (*Triticum vulgare* L.)-soil system. – in *Hungarian*). Agrokémia és Talajtan. 53. 3-4. 331-342 pp
- Svetková, K.; Henselová, M.; Morvová, M. (2005): Effects of a carbonization product as additive on the germination, growth and yield parameters of agricultural crops. Acta Agron. Hun. 53. (3). 241-250 pp
- Tanács, L., Matuz, J., Gerő, L., Petróczi, I.M. (2005): Effect of NPK Fertilizers and Fungicides on the Quality of Bread Wheat in Different Years. Cereal Res. Commun. 33 (2-3): 627-634 pp