Original Research

Characterization of Fatty Acid Composition in Eurasian Badger (*Meles meles*)

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Abstract

Polyunsaturated fatty acids (PUFAs, LA and ALA) are not synthesized in mammals in the absence of their essential fatty acid precursors. However, hibernating animals and animals sleeping through the winter need sufficiently high amounts of these acids. The Eurasian badger does not hibernate, but sleeps over winter. In the autumn the body weight of adult badgers increases even twofold, since they put on fat before the winter. Fat is deposited primarily in the subcutaneous layer of adipose tissue, and much less commonly in the muscles, liver and around the intestines. The percentage composition of fatty acids (Saturated fatty acids-SFAs, monounsaturated fatty acids-MUFAs, PUFAs) is different in particular types of tissue. The lipids isolated from depot adipose tissues (suet, subcutaneous, perirenal, periintestinal fat) are dominated by monounsaturated fatty acids (on average 41.25%), followed by saturated fatty acids (33.53%). Polyunsaturated FAs have the lowest proportion in this groups of tissues, on average 17.75% of total FAs. On the other hand, liver lipids contain over 44% PUFAs. The fatty acid composition of lipids in badgers tissue includes considerable quantities of essential unsaturated n-6 and n-3 fatty acids of great pharmacological significance.

Keywords: Eurasian badger (*Meles meles*), fatty acids, PUFAs

Introduction

Eurasian badgers are found throughout Europe and Asia. They feed on invertebrates (earthworms, mollusks, insects, beetle and wasp larvae), small mammals (mice, rabbits, rats, voles, shrews, moles, hedgehogs), ground-nesting birds and eggs, small reptiles, frogs, carrion, plant matter (acorns, nuts, berries, fruits, seeds, cereal grains, tubers, roots, bulbs) and some mushrooms. Their body weight can vary seasonally and regionally [1]. They are the largest in size at the beginning of winter, after energy had been stored as fat on their bodies during the summer and fall, and then become smaller at the beginning of spring, when all of the winter fat had been utilized. Badgers do not hibernate, but they show reduced activity in the winter.

In the spring and summer the body weights of adult badgers range from 10 to 16 kg, and in the late fall the body weights of older males may exceed 30 kg. Such significant body weight gains are caused by fat deposition before the winter, in the form of both subcutaneous layers and suet.

Studies on Eurasian badgers focus primarily on their behavior patterns in group situations, feeding habits and

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preferences [2, 3], as well as on the incidence and control of diseases spread by these animals – bovine tuberculosis, leiomyosarcoma, salmonella [4, 5, 13]. The feeding habits of the badger have been studied in agricultural land and in natural habitats characterized by different environmental conditions [11, 12]. World literature provides scant information on the nutritional value and palatability of badger meat [6] and characteristics of fats obtained from other species, e.g. the beaver or raccoon dog [7], whereas the demand for badger fat is great, at least in Poland. The product is sought after via the Internet and press ads. Badger fat has been widely used as a salve for rheumatism by folk medicine practitioners, which may have some scientific basis since it contains corticosteroids [13].

The aim of our study was to determine the fatty acid composition of fats isolated from various badger tissues and to compare these fatty acids with those extracted from other animal species (brown bear, beaver).

Materials and Methods

The experimental materials comprised samples of muscular (tenderloin) and depot adipose tissues of the European badger (*Meles meles*): fat, periintestinal tissue (fat around the intestines), subcutaneous tissue, perirenal tissue and liver. Of eight harvested animals, four adult males were selected for further investigation. They were in good physical condition, not exhausted or injured during harvest, and all were anesthetized within a short period afterwards. The fat content was determined by the modified Folch method, using a methanol-chloroform extraction mixture [10]. The fatty acid content of fat was converted into fatty acid methyl esters (FAMEs), according to the AOAC 19th Ed., Method No. 969.33.

All solutions and solvents used in the experiment were of analytical or HPLC grade. FAMEs, grouped by hydrocarbon chain length and degree of saturation, were separated by HR-GC using a 6890 Hewlett-Packard gas chromatograph with a split/splitless injector and a flame-ionization detector (FID), on a Rtx 2330 column (100m x 0.25 mm) (Restek, Bellefonte, Pennsylvania, USA). For comparative purposes, the FA composition of subcutaneous fat of the beaver and brown bear was analyzed. Qualitative and quantitative analyses of fatty acids were performed using standard solutions (Supelco Bellefonte, Pennsylvania, USA; Larodan Fine Chemicals, Malmö, Sweden).

Results and Discussion

In the Eurasian badger the fat content of particular tissues is closely related to their functions, as shown in Fig. 1.

The average amount of fat isolated from depot adipose tissues of the Eurasian badger (suet fat, subcutaneous, perirenal, periintestinal) was 68.80% in relation to crude tissue. Subcutaneous tissue contained the greatest quantity of fat – 74.97±3.22% (wet weight). The fat content of suet was only slightly lower. Subcutaneous fat and suet are the main repository fat depots in the Eurasian badger.

Analysis by high-performance gas chromatography (HP-GC) of the fatty acid composition of lipids in the above tissues of the Eurasian badger revealed the presence of fatty acids with carbon chain lengths of 12 to 22 carbon atoms.

The proportions of particular FA groups, i.e. saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs), vary depending on the kind of tissue (Fig. 2). The lipids isolated from depot adipose tissues (suet fat, subcutaneous, perirenal, periintestinal) are dominated by monounsaturated fatty acids (on average 41.25% of total FAs), followed by saturated fatty acids (33.53%). Polyunsaturated FAs have the lowest proportion in this group of tissues, on average 17.75% of total FAs.

SFAs, MUFAs and PUFAs account for 42.07%, 36.20% and about 11%, respectively, in the tenderloin muscle lipids. Liver lipids contain over 44% PUFAs, over 40% SFAs and less than 10% MUFAs.

Depot Adipose Tissues

Monoenoic Fatty Acids (MUFAs)

In the lipids from depot adipose tissues MUFAs made up from 38.13% (perirenal tissue) to 45.67% (periintestinal

Table 1. Place of harvest and animal characteristics*.

Badger no.	Place of harvest	Age (years)	Body weight (kg)
1	Łężany	6-7	18.1
2	Orneta	3-4	14.3
3	Pisz	6-7	15.2
4	Giżycko	4-5	14.8

*The following kinds of food dominated the gastric contents of all tested badgers: corn, earthworms, acorns, beechnuts, mice, grasses, wild raspberries. No detailed analysis was performed in this respect.

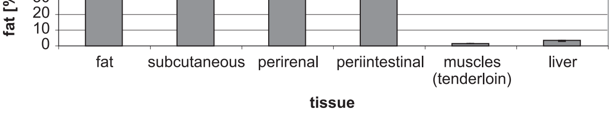

Fig. 1. Fat content of depot adipose tissues, muscular tissue and liver of the Eurasian badger. Data in the Figure include standard deviations (SD).

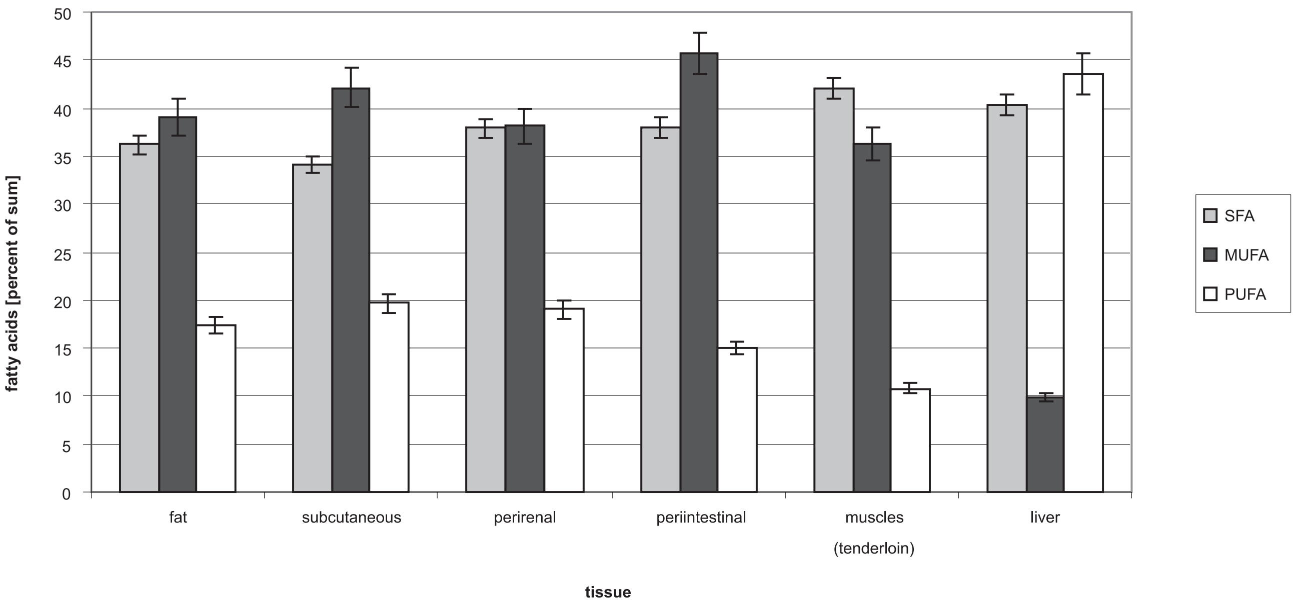

Fig. 2. Proportions of SFAs, MUFAs and PUFAs in the FA composition of tissues in the Eurasian badger.

tissue) of total FAs. The group of monoenoic FAs was dominated by oleic acid (C 18:1, 9c), palmitoleic acid (C16:1 9c) and cis-octadec-11-enoic acid (C18:1, 11c). Oleic acid (C18:1 9c) was present in the greatest amount, which is characteristic of animal fats. The level of oleic acid ranged between 23.02% of total FAs in perirenal fat and 30.43% in subcutaneous fat. For comparison, in the brown bear [7] which has a similar lifestyle to the Eurasian badger (an omnivorous animal that sleeps through the winter), subcutaneous fat contains over 42% oleic acid (Table 3).

The distinctive characteristic of fat obtained from badger's depot adipose tissues, as compared with the fat of animals that do not fall into a deep sleep in the winter, is a high concentration of palmitoleic acid (C16:1, 9c), at an average level of 9.6% of total FAs, from 7.04% to 11.28% depending on tissue (Table 2). The concentration of this acid is almost equally high in brown bears, reaching about 6.5% in subcutaneous fat [7]. Another dominant MUFA, C18:1, 11c, was present at a comparable level (3.6%) in all tissues, with slight fluctuations dependent upon the type of adipose tissue. The other monoenic fatty acids accounted for about 2% of total FAs only, showing minor variations between tissues from which fat was isolated.

Saturated Fatty Acids (SFAs).

In the lipids from depot adipose tissue saturated fatty acids form the second biggest group in terms of quantity. Their content ranges from 38.02% of total FAs in the lipids isolated from periintestinal tissue to 34.11% in the lipids extracted from subcutaneous tissue of the Eurasian badger. The group of saturated fatty acids is dominated by palmitic acid (C16:0), whose average content of depot adipose tissues is 23.78% of total FAs, ranging between 20.51% in subcutaneous fat to 25.91% in perirenal fat. The palmitic acid content of 20 – 25% is a characteristic feature of lipids in the majority of animal species (Table 3). The only exception is badger fat, which contains 8.7% to 17.5% of this acid, depending on the type of adipose tissue.

Stearic acid, the second most common acid in terms of quantity, accounts for 5.55% to 8.82% of total FAs, depending on tissue from which it was extracted. Subcutaneous tissue of the Eurasian badger and brown bear contains 8.82% and about 8.0% of total FAs, respectively. Pork fat, which is the main source of saturated fatty acids in the human diet, contains over 12% stearic acid.

Polyunsaturated Fatty Acids (PUFAs)

Polyunsaturated fatty acids have the lowest proportion in the total FA composition in adipose tissues of the Eurasian badger (Table 2), from 15.01% in periintestinal tissue to almost 20% in subcutaneous fat. The average level of linoleic acid (LA, C18:2, n-6), a precursor to long-chain unsaturated n-6 fatty acids, in depot adipose tissues of the Eurasian badger is 9.49%. This level is lower than in the lipids of the European beaver, where the LA content is about 20%. On the other hand, the LA content of bear fat, just like beaver fat known for its health-promoting properties, is "only" about 4% of total FAs. The level of α-linolenic acid (ALA, C18:3 n-3), a precursor to essential unsaturated n-3 fatty acids, is on average 2% of total FAs in adipose tissues of the Eurasian badger, which places it between the ALA content of beaver fat – about 16% and the ALA content of bear fat – 1.4% [7]. The levels of LA and ALA are similar in all depot adipose tissues of the Eurasian badger, regardless of the kind of tissue from which they were taken.

Special attention should be paid to the high concentrations of LA and ALA metabolites in adipose tissues of the Eurasian badger, i.e. long-chain polyunsaturated FAs (LC PUFAs) such as dihomo-γ-linolenic acid

Table 2. Composition of particular fatty acids in depot adipose tissues, tenderloin muscle and liver of of the Eurasian badger (%total FAs, mean ± SD).

Fatty acid	Liver	Fat	Subcutaneous fat	Perirenal fat	Periintestinal fat	Tenderloin
C 12:0	tr.	0.48 ± 0.01	0.28 ±0.01	0.43 ± 0.01	0.49 ± 0.01	0.41 ± 0.01
C 14:0	0.74 ± 0.02	3.65 ± 0.10	3.44 ±0.11	4.92 ± 0.15	4.98 ± 0.02	3.99 ± 0.13
C 15:0	0.50 ± 0.04	0.39 ± 0.03	0.41 ±0.04	0.35 ± 0.03	0.24 ± 0.02	0.16 ± 0.01
C 16:0	13.18 ± 0.30	23.87 ± 0.55	20.51 ±0.47	25.91 ± 0.60	24.82 ± 0.57	22.95 ± 0.53
C 17:0	2.97 ± 0.15	0.66 ± 0.03	0.66 ± 0.04	0.74 ± 0.04	0.43 ± 0.02	1.33 ± 0.07
C 18:0	22.98 ± 0.80	7.13 ± 0.25	8.82 ± 0.31	5.55 ± 0.19	7.06 ± 0.25	13.24 ± 0.66
Σ SFA	**40.37 ± 1.08**	**36.18 ± 0.98**	**34.11 ± 0.91**	**37.91 ± 1.01**	**38.02 ± 1.02**	**42.01 ± 1.12**
C 14:1	0.53 ± 0.04	0.34 ± 0.03	0.30 ± 0.03	0.36 ± 0.04	0.27 ± 0.02	0.37 ± 0.04
C 16:1, 9c	0.49 ± 0.04	8.72 ± 0.68	7.04 ± 0.55	11.20 ± 0.87	11.28 ± 0.88	7.89 ± 0.62
C 17:1	tr.	0.42 ± 0.04	0.41 ± 0.04	0.32 ± 0.03	0.38 ± 0.04	0.25 ± 0.03
C18:1, 9c	4.73 ± 0.15	25.57 ± 0.86	30.43 ± 0.97	23.02 ± 0.74	29.40 ± 0.94	22.95 ± 0.73
C 18:1, 11c	4.15 ± 0.23	3.82 ± 0.22	3.59 ± 0.21	3.01 ± 0.20	4.12 ± 0.23	4.50 ± 0.24
C 20:1	tr.	0.18 ± 0.02	0.37 ± 0.03	0.22 ± 0.02	0.22 ± 0.02	0.23 ±0.02
Σ: MUFA	**9.90 ± 0.47**	**39.05 ± 1.85**	**42.13 ± 2.01**	**38.13 ± 1.81**	**45.67 ± 2.17**	**36.20 ± 1.72**
C 18:2 (n-6) LA	8.89 ± 0.22	8.69 ± 0.21	10.62 ± 0.25	9.77 ± 0.24	8.76 ± 0.16	6.46 ± 0.16
C 20:3 (n-6) DGLA	2.16 ± 0.17	0.51 ± 0.04	0.63 ± 0.05	0.58 ± 0.05	0.31 ± 0.02	0.39 ± 0.03
C 20:4 (n-6) AA	16.60 ± 1.59	1.97 ± 0.19	2.09 ± 0.20	2.05 ± 0.20	1.46 ± 0.14	1.65 ± 0.13
C 22:4 (n-6)	2.27 ± 0.29	0.50 ± 0.06	0.32 ± 0.04	0.60 ± 0.08	0.27 ± 0.04	0.24 ± 0.03
C 22:5 (n-6)	tr.	0.20 ± 0.04	0.30 ± 0.06	0.21 ± 0.02	0.13 ± 0.02	0.06 ± 0.01
Σ PUFA (n-6)	**29.92 ± 1.36**	**11.87 ± 0.54**	**13.97 ± 0.63**	**13.20 ± 0.60**	**10.93 ± 0.50**	**8.80 ± 0.04**
C 18:3 (n-3) ALA	1.10 ± 0.03	2.14 ± 0.06	2.03 ± 0.06	2.05 ±0.06	1.78 ± 0.05	0.54 ± 0.02
C 20:5 (n-3) EPA	2.28 ± 0.18	1.07 ± 0.09	1.61 ± 0.13	1.23 ± 0.10	0.96 ± 0.08	0.31 ± 0.02
C 22:5 (n-3) DPA	7.98 ± 0.56	0.95 ± 0.00	0.84 ± 0.06	1.24 ± 0.09	0.53 ± 0.04	0.38 ± 0.03
C 22:6 (n-3) DHA	0.80 ± 0.05	0.31 ± 0.02	0.36 ± 0.02	0.51 ± 0.03	0.30 ± 0.02	0.10 ± 0.01
Σ PUFA (n-3)	**12.16 ± 0.65**	**4.47 ±0.24**	**4.84 ± 0.26**	**5.04 ± 0.27**	**3.57 ± 0.19**	**1.33 ± 0.07**
(n-3) / (n-6)	1.23	0.38	0.34	0.38	0.33	0.15
C 22:2 (n-9)	1.39 ± 0.11	0.96 ± 0.07	0.89 ± 0.07	0.78 ± 0.06	0.51 ± 0.04	0.63 ± 0.05
Σ PUFA	**43.47 ± 2.13**	**17.30 ± 0.85**	**19.67 ± 0.97**	**19.02 ± 0.93**	**15.01 ± 0.74**	**10.76 ± 0.61**

* tr – trace

A distinctive feature of the lipids from adipose tissues in the Eurasian badger is a high concentration of myristic acid (C14:0), ranging from 3.44% of total FAs in suet fat to 4.98% in periintestinal tissue. Pork fat contains 2 – 2.5% myristic acid, subcutaneous tissue of the brown bear – about 1.8% [7], and the lipids from adipose tissues of the European beaver – about 1%.

DGLA (C20:3 n-6), arachidonic acid AA (C20:4 n-6), eicosapentaenoic acid EPA (C20:5 n-3) and docosapentaenoic acid DPA (C22:5 n-3), which are found in trace amounts only in tissues of other animal species. DGLA is a direct precursor to the series 1 prostaglandins, and the series 3 thromboxanes and leucotriens, so it plays a significant physiological role. The DGLA content of the lipids from subcutaneous tissue is 0.31% to 0.63% in the Eurasian badger, and 0.10% in the brown bear and European beaver. Another n-6 LC PUFA, arachidonic acid AA, which is a precursor to the series 2 prostaglandins and the series 4 thromboxanes, accounts for about 2% of total FAs in depot adipose tissues of the Eurasian badger. For comparison, the AA content of lipids of the European beaver and brown bear is 0.25% and about 0.3%, respectively.

Table 3. Composition of some fatty acids in subcutaneous tissues of the badger, brown bear and beaver (% of total FAs, mean ± SD).

Fatty acid	Badger fat	Brown bear fat*	Beaver fat
12:0 lauric	0.28	ND	0.06
14:0 myristic	3.44	1.80	0.99
16:0 palmitic	20.51	24.70	16.06
18:0 stearic	8.82	8.00	5.29
16:1, 9c palmitoleic	7.04	6.50	1.22
18:1 9c oleic	30.43	42.70	19.90
18:2 (n-6) LA	10.62	4.10	27.78
20:3 (n-6) DGLA	0.63	0.10	0.10
20:4 (n-6) AA	2.09	0.30	0.22
18:3 (n-3) ALA	2.03	1.40	16.23
20:5 (n-3) EPA	1.61	0.10	tr
20:5 (n-3) EPA	0.84	0.20	0.23
22:6 (n-3) DHA	0.36	0.10	tr

*Käkelä and Hyvärinen, 1996; tr. – trace

Similarly, extremely valuable n-3 LC PUFAs like EPA, DPA and DHA, characteristic rather of fish lipids than of the lipids of terrestrial animals, are present at relatively high levels in badger fat. The mean concentrations of EPA, DPA and DHA are 1.21%, 0.90% and 0.33% of total FAs. The above metabolites of LA and ALA are found in trace quantities only in adipose tissues of other terrestrial animal species (Table 4).

Muscular Tissue Lipids

Saturated fatty acids, including palmitic acid (C16:0), stearic acid (C18:0) and myristic acid (C14:0), dominate quantitatively in the lipids from muscular tissue. A characteristic feature of badger's tissues is a high (almost 4%) level of myristic acid (C14:0). The group of MUFAs extracted from muscular tissue lipids in the Eurasian badger is dominated by oleic acid (C18:1 9c), whose content of this tissue is about 5% of total FAs lower than in depot adipose tissues. Next comes palmitoleic acid (C16:1 9c) – nearly 8% of total FAs and cis-octadec-11-enoic acid (C18:1 11c) – about 4.5%. PUFAs account for only 10.76% of total FAs in the muscular tissue lipids of the Eurasian badger, but the level of LC PUFAs, especially n-6 ones, is still high for animal lipids.

Liver Lipids

The lipids obtained from the badger's liver, similarly as the lipids isolated from the livers of other animals, have a high PUFA content (43%). However, the lipids from the badger's liver, just like other tissues of this animal species, have a high content of n-3 and n-6 LC PUFA metabolites. In comparison with the beaver, the lipids from the badger's liver contain much lower amounts of precursors to unsaturated fatty acids: linoleic acid C 18:2 (n-6) accounts for 8.89% of total FAs in the badger and for 29% in the beaver, and α-linolenic acid C18:3 (n-3) makes up about 1% in the badger and about 3.5% in the beaver.

The sum of n-6 and n-3 LC PUFA products in the lipids from the badger's liver is almost twofold higher than in the lipids from the beaver's liver, i.e. 21% of total FAs versus about 12% in the case of n-6 products, and 11% versus

Table 4. Composition of selected fatty acids isolated from the liver of the Eurasian badger and European beaver (%).

Fatty acid	Badger's liver	Beaver's liver*
18:2 (n-6) LA	8.89	29.48
20:3 (n-6) DGLA	2.16	1.47
20:4 (n-6) AA	16.60	10.44
22:4 (n-6)	2.27	0.43
22:5 (n-6)	tr.	tr.
Σ (n-6) products	**21.03**	**12.34**
18:3 (n-3) ALA	1.10	3.45
20:5 (n-3) EPA	2.28	0.19
22:5 (n-3) DPA	7.98	0.17
22:6 (n-3) DHA	0.80	0.26
Σ (n-3) products	**11.06**	**1.62**

* own study

1.6% in the case of n-3 products. The group of n-6 products is characterized by a high level of arachidonic acid AA (16.6%) and a very high proportion of docosatetraenoic acid C22:4 (n-6), not found in the animal species that do not fall into a winter sleep. Docosapentaenoic acid DPA C22:5 (n-3) that dominates among n-3 LC PUFAs accounts for nearly 8% of total FAs in the lipids from the badger's liver.

Conclusions

Studies on the lipids of the Eurasian badger have many interesting aspects. The most fundamental problem is the comparison of the composition of fatty acids, especially unsaturated acids, in the badger and in hibernating animals, as well as in animals that do not hibernate and do not sleep through the winter. The nutritional value of the badger carcass is also worth investigating.

Badger meat is still occasionally consumed as a delicacy in Croatia [6]. Just like other wild animals, the Eurasian badger falls into a light sleep in order to survive through the season of cooling and food shortage [8, 9]. In comparison with the black bear, ground squirrel, alpine marmot, ground hog, black-tailed prairie dog, American mouse or some species of chiropters, the badger's sleep is light and as soon as the warmer weather comes the animal is ready to leave the set and start foraging for food.

The FA composition of depot adipose tissues taken from various body parts of the Eurasian badger is generally similar. The lipids from badger's tissues contain acids typical of animal fats, such as palmitic acid (C16:0) and stearic acid (C18:0). However, their mean levels are lower than in typical depot fat of terrestrial animals, and higher than in the lipids of beaver's adipose tissues.

The analysis of the lipids obtained from Eurasian badger's tissues shows that the feature that distinguishes badger's lipids from the lipids of animals that do not fall into a winter sleep is a high concentration of myristic acid C14:0 (over 3.4% of total FAs) and palmitoleic acid C16:1 9c (over 7%). The fatty acid composition of lipids in badger's tissues includes considerable quantities of essential unsaturated n-6 and n-3. n-6 and n-3 metabolites are fatty acids found very rarely in animal adipose tissues, since n-6 metabolites are typical of vegetable oils, whereas n-3 metabolites – of fish fats.

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