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BIODIVERSITY OF SEGETAL FLORA IN POTATO FIELDS (*SOLANUM TUBEROSUM* L.) IN SELECTED MUNICIPALITIES OF THE ZAMOŚĆ REGION

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K e y w o r d s: potato, weed infestation, soil-agricultural complexes.

A b s t r a c t

The research was conducted on weed infestation of potato crops in fields with different soils in several (9) municipalities in the Zamość region in 2014–2015 were compared with the results of research carried out in 1991–1995. The phytosociological photos were created by Braun-Blanquet's method, of which 87 representative images were selected for analysis. The photos were taken on three complexes of agricultural suitability of soils: good wheat, defective wheat and good rye.

Generally identified 55 species of weeds (43 annual and biennial and 12 perenial). The cultivation of potato less were infested on the complex good wheat and defective than good rye. One photo in the first research period (1991–1995) accounted from 45 to 52 species, while in the second period (2014–2015) from 41 to 49 species. In potato canopy dominated nitrophilous species: *Chenopodium album, Echinochloa crus-galli, Matricaria maritima subsp. inodora, Stellaria media, Galinsoga parviflora, Elymus repens* and *Equisetum arvense.*

In general, irrespective of the soil complex, the resumption of testing after 20 years in selected locations in various municipalities of the Zamość region indicates is very limited of certain taxa, such as *Galeopsis tetrahit*, *Veronica persica*, *Papaver rhoeas, Avena fatua, Sinapis arvensis*, *Spergula arvensis*, *Fallopia convolvulus* and *Polygonum persicaria,* in addition to *Galium aparine* and *Stellaria media* on poorer soil complexes. An increase in infestation of potato was noted for *Chenopodium album*, *Echinochloa crus-galli*, *Setaria pumila*, *Anthemis arvensis*, *Atriplex patula* and *Lamium purpreum*. Among perennial taxa, crops are infested in the highest degree by *Elymus repens* and *Equisetum arvense*.

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BIORÓŻNORODNOŚĆ FLORY SEGETALNEJ W UPRAWACH ZIEMNIAKA (*SOLANUM TUBEROSUM* L.) W WYBRANYCH GMINACH ZAMOJSZCZYZNY

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S ł o w a k l u c z o w e: uprawa ziemniaka, zachwaszczenie, kompleksy glebowo-rolnicze.

A b s t r a k t

Badania nad zachwaszczeniem upraw ziemniaka przeprowadzono na polach uprawnych na różnych glebach w kilku gminach (9) na Zamojszczyźnie w latach 2014–2015 i porównano je z wynikami badań z lat 1991–1995. Wykonano zdjęcia fitosocjologiczne metodą Braun-Blanqueta, z których do analizy wybrano 87 reprezentatywnych zdjęć. Zdjęcia te wykonano na trzech kompleksach rolniczej przydatności gleb: pszenny dobry, pszenny wadliwy i żytni dobry.

Ogólnie rozpoznano 55 gatunków chwastów (32 krótkotrwałe i 12 wieloletnich). Pola uprawne z ziemniakiem były mniej zachwaszczone na kompleksie pszennym dobrym niż pszennym wadliwym i żytnim dobrym. Na jedno zdjęcie w I okresie badań (1991–1995) przypadało od 45 do 52 gatunków chwastów, podczas gdy w II okresie (2014–2015) od 41 do 49 taksonów. W łanach ziemniaka dominowały gatunki nitrofilne: *Chenopodium album, Echinochloa crus-galli, Matricaria maritima subsp. inodora, Stellaria media, Galinsoga parviflora, Elymus repens* i *Equisetum arvense.*

Niezależenie od kompleksu rolniczej przydatności gleb po wznowieniu badań po 20 latach w wybranych lokalizacjach gmin Zamojszczyzny stwierdza się bardzo ograniczone występowanie niektórych taksonów, jak: *Galeopsis tetrahit, Veronica persica, Papaver rhoeas, Avena fatua, Sinapis arvensis, Spergula arvensis, Fallopia convolvulus* i *Polygonum persicaria*, ponadto na kompleksach słabszych – *Galium aparine* i *Stellaria media.* Wzrasta natomiast zachwaszczenie łanów ziemniaka przez: *Chenopodium album, Echinochloa crus-galli, Setaria pumila, Anthemis arvensis, Atriplex patula* i *Lamium purpreum.* Ponadto z taksonów wieloletnich uprawy obecnie zachwaszczane są w najwyższym stopniu przez *Elymus repens* i *Equisetum arvense.*

Introduction

Potato plants are highly vulnerable to weed infestation because they are grown in wide rows, which creates favourable conditions for weed development. Secondary weed infestation in particular significantly reduces potato yields, by as much as 10–70%. An increase of one plant per square meter decreases the yield of potato tubers by 0.05–0.15 t ha^{-1} (ZARZECKA et al 2004). Weeds are highly competitive with potato for nutrients, water and light, and reduce the quality of harvested crops. Potato crops in Poland are infested with about 200 weed species, of which only a few play a dominant role among the weeds. The floristic composition of weed communities and the degree of infestation in crop fields depends on numerous natural and artificial habitat factors. Characteristic weed species are known to be associated with particular crop plants, soil types, soil pH, moisture, and content of humus and minerals

(BUJAK and FRANT 2006, KRASKA et al. 2006, RÓŻYŁO and PAŁYS 2008, ZARZECKA et al. 2009, SAWICKA et al. 2011, GARGAŁA and TRĄBA 2014, GUGAŁA et al. 2014). Besides natural factors, anthropogenic factors, such as the type and intensity of cultivation procedures, including herbicide application, play an equally important role (KLIKOCKA and WESOŁOWSKI 2002, ZARZECKA et al. 2013). Suitably chosen crop protection products ensure nearly complete destruction of the weeds infesting the crop and at the same time effectively eliminate segetal flora diversity (ROLA and ROLA 2001). Dicotyledonous species are eliminated first, particularly on the poorest soils and rendzinas.

The aim of the study was to evaluate the degree of changes in secondary weed infestation of potato in the years 1991–1995 and 2014–2015 on arable fields in selected municipalities of the Zamość region.

Material and Methods

A phytosociological analysis was performed by Braun-Blanquet's method (BRAUN-BLANQUET 1964) in two periods, I – 1991–1995 and II – 2014–2015, in the municipalities of Józefów, Susiec, Adamów, and Tomaszów Lubelski (Central Roztocze), Radecznica (West Roztocze), Obsza (Sandomierz Basin), and Hrubieszów, Werbkowice, and Tyszowce (Lublin Upland). Characterization of the weed infestation of individual soil types was based on 87 representative phytosociological relevés, were selected for analysis. An attempt was made to distribute the research plots in such a way as to represent the spatial diversity of ecological conditions in the area. Complexes of agricultural suitability of soils were identified on the basis of agricultural soil maps with a scale of 1:5,000, prepared by the Provincial Bureau of Surveying and Agricultural Areas in Zamość.

Phytosociological relevés in the potato crops were prepared in the second half of August. Weed species were recorded from an area of about 100 m^2, selecting the most homogeneous and uniform patches in terms of density of crop plants and weeds. The phytosociological constancy and cover index of species was determined in the segetal communities of the potato crop. Phytosociological constancy (S) is the frequency of occurrence of individual species in the relevés, on Braun-Blanquet's five-point scale (I–V) (BRAUN-BLANQUET 1964, PAWŁOWSKI 1982). The cover index (D) was calculated using Braun-Blanquet's seven-point scale: 5 = 87.5%; 4 = 62.5%; 3 = 37.5%; 2 = 17.5%; 1 = 2.5%; + up to 1.0%, and r up to 0.1%. The species posing the greatest threat to the potatoes were identified using a 5-degree weed infestation scale (BOROWIEC 1984, KORNIAK 1992) – Table 1. It takes into account both the degree of constancy (S) and the cover index (D) of the weeds. The

dominance index and the Shannon total diversity index were calculated according to ODUM (1982). Species nomenclature was given according to MIREK et al. (2002).

Table 1

Degrees of an infestation of crops by weed species

The degree of an infestation	Phytosociological constancy (S)	Cover index (*D*)
1 – very large	V, IV	>500
2 – large	V, IV, III	300–499 >500
3 – average	V, IV III	100–299 200–499
4 – small or large locally	V, IV III II	< 100 100–199 > 100
5 – occasional	I, II	< 100

Physical and geographical characteristics of the area

The Zamość region is situated in south-eastern Poland. Its precise location is defined by the following coordinates: east longitude from 11°24'' to 24°09'' and north latitude from 50°15'' to 51°00''. Its longitudinal distance is 86 km and its latitudinal distance is 122 km. The total area of the Zamość region is 6,307 km^2, which is 1.6% of the area of Poland. The following macroregions are distinguished in the Zamość region: the Lublin Upland, Roztocze, the Sandomierz Basin, Volhynian Polesie, the Zachodnio-Wołyńska Upland and Pobuże (KONDRACKI 1980).

As bedrock of arable soils Quaternary and Pleistocene materials (loess, silt, sand and loam) predominate, occupying 65% of the surface area. Their average thickness ranges from 10 to 15 m. Older Cretaceous (Senon) and Tertiary (Miocene) sediments cover about 15% of the area, with younger Holocene deposits (alluvial and fluvial sands and peat deposits) accounting for the remaining 20% (KONDRACKI 1980).

The percentages of particular soil types in the surface area of agricultural land are as follows: Haplic Podzol and Haplic Luvisol – 14.6%, Haplic Cambisol (Eutric) – 12.1%, Haplic Cambisol – 34.4%, Calcic Chernozem and Haplic Chernozem – 14.6%, and other soils (Gleyic Chernozem, Haplic Gleysol, Haplic Fluvisol, Fluvic Cambisol, Cambic Leptosol, Rendzic Phaeozem) (PTG 2011) – 24.3%. Very light soils account for 7%, light soils 53%, moderately heavy 30.4%, and heavy or very heavy 9.6%. In terms of granulometric composition, loess soils occupy the largest area of agricultural land (66%), followed by

cretaceous limestone (7.6%), loam (6.4%), loamy sand (5.2%), loose sand and weak clay (7.2%) and organogenic material (7.6%). About 70% of arable land in the Zamość region is characterized by relatively optimal moisture levels; 12% of soils are periodically or permanently wet, while 19% are periodically or permanently dry (KERN et al. 1990, GUS 2015).

In the Lublin Upland wheat complex soils dominate: good (2), very good (1) and defective (3). Roztocze is characterized by a predominance of poorer soils, specifically good (5) and very good (4) rye complex soils, as well as defective wheat complex (3). In the Sandomierz Basin very good rye complex soils (4) are dominant.

In the former Zamość Voivodeship very good wheat complex soils, according to polish agricultural soil classification occupy 22.2% of the total area of arable land, while good wheat complex soils occupy 27.4%, and defective wheat complex soils account for only 9.3%. The percentage share of rye complexes is lower: very good – 13.7%, good 16.5%, poor 5.8%, and very poor rye complex just 2.7%.

Agricultural land occupies 71.8% of the area of the Zamość region and arable land accounts for 58.6%. The percentage shares of soil complexes in the selected municipalities were quite varied, as shown in Table 2. The agrochemical properties of the soils in the municipalities are presented in Table 3.

The Zamość region has little surface water. The entire area is included in the catchment of the Vistula, a first-order river. The main river is the Wieprz, a second-order river, together with its tributaries. The eastern part of the

Table 2

Characteristics of the soil in the Zamość region (KERN et al. 1990)

Physiographic region	Municipality	The complex of agricultural suitability of soils [%]			Quality index of agricultural production space*
		good wheat (2)	defective wheat (3)	good rye (5)	
Roztocze Środkowe	Józefów	0.8	6.5	26.9	60.5
	Susiec	0.0	12.2	28.8	60.3
	Adamów	31.0	48.5	4.7	79.8
	Tomaszów Lub.	15.9	25.9	19.2	75.1
Roztocze Zachodnie	Radecznica	33.1	45.9	12.7	81.7
Kotlina Sandomierska	Obsza	7.9	0.1	11.3	74.4
Wyżyna Lubelska	Hrubieszów	17.7	1.4	1.1	104.5
	Werbkowice	45.2	2.7	0.8	93.5
	Tyszowce	40.8	9.0	4.9	88.3

* Evaluation of agro-ecological conditions in 50–100 points

Table 3

Agrochemical characterization of soils in the Zamość region (KERN et al. 1990)

Physiographic region	Municipality	Bonitation indicator negative [%]* (arable land)			Acidic soils share [%] (agricultural land)
		phosphorus	potassium	magnesium	
Roztocze Środkowe	Józefów	81	67	76	89.0
	Susiec	90	60	78	96.8
	Adamów	49	79	83	91.7
	Tomaszów Lub.	69	75	76	85.5
Roztocze Zachodnie	Radecznica	53	65	53	77.1
Kotlina Sandomierska	Obsza	77	93	89	99.0
Wyżyna Lubelska	Hrubieszów	42	67	29	51.8
	Werbkowice	41	68	44	38.8
	Tyszowce	49	67	42	52.4

* Percentage of the soil requires increased fertilization

Zamość region is drained by the Bug River, and especially by its left tributary the Huczwa. From the south-western part the surface waters flow directly into the San, a second-order river, by way of the Tanew and its tributaries (Sopot, Szum, Czarna Łada and Biała Łada). The Pobuże region is drained to the east by the Solokiya River, a left tributary of the Bug. At the foot of Roztocze there are numerous springs.

The occurrence of groundwater is associated with the geological structure of the area. In the Zamość region we can distinguish areas with the following groundwater depths: from 0 m to 5 m (south-western part of the region included in the Biłgoraj Plain, the Tarnogród Plateau, east of the Huczwa River Valley, and the Bug River Valley); from 5 m to 20 m (areas outside of valleys covered with silty sand and till, the Zamość Depression, and Roztocze); over 20 m (the Giełczew Elevation, the Grabowiec Interfluves, the Lublin Upland, Western Roztocze, and the eastern part of the Sokal Ridge).

The current climate of the Zamość region can be characterized as transitional, shaped by an influx of oceanic or continental air masses, predominantly continental, of variable range. Mean precipitation is 417 mm during the growing season and 172 mm in the autumn and winter. The mean air temperature is 7°C. Temperatures are below 0°C in December, January and February, on average from –1 to –4°C. Summers are hot, particularly in June, July and August, on average 17°C (KLIKOCKA et al. 2015).

Results

In the selected municipalities of the Zamość region 55 weed species were noted in the potato crops. Among these 43 were annuals and biennials taxa and 12 were perennial (Table 4). Irrespective of the soil complex, there were 45 to 52 species per relevé in the first period of the study (1991–1995) and from 41 to 49 species in the second period (2014–2015). This means that 20 years after the first part of the study the number of segetal species in the potato crops had decreased. The weed infestation was dominated by annuals and biennials species (on average 68.6%) and dicotyledonous species (on average 87.8%) over perennial species (31.4%) and monocotyledonous species (12.3%) – Table 4. The mean cover index (*D*) ranged from 318 to 555 and was higher during the second period of the study (2014–2015) and on the good rye complex soils (5). A similar tendency was observed for the ecological indices, the dominance index and Shannon's diversity index, with higher values in 2014–2015.

Table 4

Diversity of segetal weeds in potato canopy

Specification	I period (years 1991–1995)			II period (years 2014–2015)			CV%**
Complex of agricultural suitability of soils*	2	3	5	2	3	5	–
Number of phytosociological photo	14	14	14	15	15	15	–
Total number of species (no)	46	45	52	41	41	49	9.56
Means cover index (*D*)	318	354	358	355	432	555	21.92
Dicotylodonus (no)	41	40	47	36	36	46	11.54
Monocotylodonus (no)	5	5	5	5	5	3	17.50
Annuals and bienials (no)	35	35	41	30	31	38	11.85
Perennials (no)	11	10	11	11	10	11	4.84
Dominance index	0.116	0.095	0.096	0.141	0.115	0.125	15.29
Shannon's total diversity index	0.667	0.610	0.614	0.698	0.678	0.709	6.32

* Complex of agricultural suitability of soils: 2 – good wheat, 3 – defective wheat, 5 – good rye
** CV% – coefficient of variation

Stellaria media and *Chenopodium album* were present in the highest (1) and a high (2) degree of infestation in the first period of the study (1991–1995) on all three complexes. In the second period of the study (2014–2015) the degree of infestation was very high only for *Chenopodium album*, while *Stellaria media* decreased to a sporadic level (5). *Echinochloa crus-galli* most heavily infested the potato plantations on the good wheat and good rye complexes, but did not pose a threat (5th degree of infestation) on the defective wheat complex. Markedly reduced infestation with this taxon was observed in 2014–2015, where it decreased to the 4th degree on the good wheat complex and to the second degree on the good rye complex. The defective wheat complex remained unchanged (Table 5).

Table 5

A statement of the degree of phytosociological constancy (S), cover index (*D*) and the degree of an infestation (*Z*) of potato cultivation on good wheat complex (2)

No.	Species	Years of study					
		1991–1995			2014–2015		
		S	*D*	*Z*	S	*D*	*Z*
1	2	3	4	5	6	7	8
Annuals and biennials							
1.	*Stellaria media* (L.) Vill.	V	938	1	I	79	5
2.	*Chenopodium album* L.	IV	538	1	IV	606	1
3.	*Echinochloa crus-galli* (L.) P. Beauv.	IV	658	1	II	579	4
4.	*Galinsoga parviflora* Cav.	III	493	3	I	79	5
5.	*Setaria pumila* (Poir.) Roem. & Schutt.	III	393	3	III	579	2
6.	*Galium aparine* L.	III	63	4	I	97	5
7.	*Galeopsis tetrahit* L.	III	161	4	I	2	5
8.	*Polygonum persicaria* L.	II	19	5	I	3	5
9.	*Fallopia convolvulus* (L.) H. Löve	II	20	5	II	34	5
10.	*Spergula arvensis* L.	II	69	5	–	–	–
11.	*Matricaria maritima* L. *subsp.inodora* (L.) Dostal	II	374	4	II	368	4
12.	*Veronica persica* Poir.	II	46	5	I	6	5
13.	*Papaver rhoeas* L.	II	20	5	–	–	–
14.	*Sinapis arvensis* L.	I	10	5	–	–	–
15.	*Atriplex patula* L.	I	2	5	III	634	2
16.	*Amaranthus retroflexus* L.	I	2	5	I	118	5
17.	*Lamium purpureum* L.	I	3	5	I	95	5
18.	*Thlaspi arvense* L.	I	4	5	–	–	–
19.	*Avena fatua* L.	I	4	5	I	1	5
20.	*Anagalis arvensis* L.	I	5	5	I	4	5
21.	*Viola arvensis* Murray	I	5	5	I	4	5
22.	*Vicia hirsuta* (L.) S.F. Gray	I	2	5	I	1	5
23.	*Vicia tetrasperma* (L.) Schreb.	I	3	5	I	2	5
24.	*Vicia angustifolia* L.	I	2	5	I	1	5
25.	*Apera spica-venti* (L.) P.B.	I	1	5	I	1	5
26.	*Geranium pussilum* Burm. f. ex L	I	2	5	I	1	5
27.	*Centaurea cyanus* L.	I	1	5	I	1	5
28.	*Anthemis arvensis* L.	–	–	–	–	–	–
29.	*Veronica arvensis* L.	I	4	5	I	3	5
30.	*Sonchus asper* (L.) Hill.	I	2	5	I	1	5
31.	*Sonchus oleraceus* L.	I	1	5	–	–	–
32.	*Capsella bursapastoris* (L.) Medik.	I	2	5	I	1	5
33.	*Myosotis arvensis* (L.) Hill	–	–	–	–	–	–
34.	*Polygonum aviculare* L.	–	–	–	–	–	–
35.	*Galinsoga cilliata* (Raf.) S. F. Blake	–	–	–	–	–	–
36.	*Thlapsi arvense* L.	I	1	5	I	1	5
37.	*Erodium cicutarium* (L.) L'H.	I	1	5	I	1	5
38.	*Poa annua* L.	I	2	5	I	1	5
39.	*Senecio vulgaris* L.	–	–	–	–	–	–
40.	*Scleranthus annus* L.	–	–	–	–	–	–
41.	*Setaria viridis* (L.)P. Beauv.	I	2	5	I	2	5
42.	*Melandrium album* (Mill.) Garcke	–	–	–	–	–	–
43.	*Conyza canadensis* (L.) Cronquist	–	–	–	–	–	–

cont. table 5

1	2	3	4	5	6	7	8
	Perenials						
44.	*Elymus repens* (L.) Gould	III	159	4	V	1514	1
45.	*Equisetum arvense* L.	III	299	3	III	164	4
46.	*Convolvulus arvensis* L.	III	98	4	II	205	4
47.	*Cirsium arvense* (L.) Scop.	II	30	5	III	136	4
48.	*Plantago maior* L.	I	2	5	I	2	5
49.	*Plantago lanceolata* L.	I	1	5	I	1	5
50.	*Taraxacum officinale* F.H. Wigg.	I	1	5	I	1	5
51.	*Rumex acetosella* L.	I	2	5	I	1	5
52.	*Trifolium repens* L.	I	1	5	I	1	5
53.	*Lotus corniculatus* L.	I	1	5	I	1	5
54.	*Trifolium arvense* L.	–	–	–	–	–	–
55.	*Artemisia campestris* L.	I	1	5	I	1	5

The good wheat complex (2) in the first period of the study (1991–1995) was also heavily infested with *Galinsoga parviflora*, *Setaria pumila*, *Galeopsis tetrahit*, *Spergula arvensis* and *Galium aparine*. Among perennial taxa, the highest infestation was caused by *Elymus repens*, *Equisetum arvense* and *Convolvulus arvensis*. In the second period of the study (2014–2015) there was a reduction in the occurrence of *Galinsoga parviflora* and *Galium aparine* (1st degree of infestation), whereas an increase was noted in infestation by *Matricaria maritima* ssp. *indora* (1st degree of infestation). Among perennial taxa, higher frequency was noted for *Equisetum arvense*, *Elymus repens* and *Convolvulus arvensis*. Overall, 46 taxa were observed on the complex 2 soils (good wheat) in 2010–2011, including 35 annuals and biennials and 11 perennial species, and 41 dicotyledonous and 5 monocotyledonous species. In the second period of the study, conducted in 2014–2015, 41 taxa were counted (30 annuals and biennials and 11 perennial species; 36 dicotyledonous and 5 monocotyledonous species). In the second period of the study, in contrast with the first, *Spergula arvensis*, *Papaver rhoeas*, *Sinapis arvensis*, *Thlaspi arvense* and *Sonchus oleraceus* were not recorded.

The annuals and biennials taxa *Anthemis arvensis*, *Myosotis arvensis*, *Polygonum aviculare*, *Senecio vulgaris*, *Sclaranthus annus*, *Melandrium album*, *Conyza canadensis* and the perennial taxon *Trifolium pretense* were not observed in the defective wheat complex or good rye complex soil.

The defective wheat complex (3) in the first period of the study was heavily infested with *Stellaria media*, *Chenopodium album*, *Galium aparine*, *Fallopia convolvulus*, *Veronica persica*, *Papaver rhoeas*, *Sinapis arvensis* and *Avena fatua* (Table 6). Among perennial weeds, the potatoes were most heavily

Table 6

A statement of the degree of phytosociological constancy (S), cover index (*D*) and the degree of an infestation (*Z*) of potato cultivation on defective wheat complex (3)

No.	Species	Years of study					
		1991–1995			2014–2015		
		S	*D*	*Z*	S	*D*	*Z*
1	2	3	4	5	6	7	8
Annuals and biennials							
1.	Stellaria media (L.) Vill.	V	679	1	I	10	5
2.	*Chenopodium album* L.	V	672	1	V	1118	1
3.	*Echinochloa crus-galli* (L.) P. Beauv.	I	33	5	I	614	5
4.	*Galinsoga parviflora* Cav.	II	84	5	II	432	4
5.	*Setaria pumila* (Poir.) Roem. & Schutt.	II	25	5	II	545	4
6.	*Galium aparine* L.	V	543	1	I	4	5
7.	*Galeopsis tetrahit* L.	I	15	5	I	1	5
8.	*Polygonum persicaria* L.	II	16	5	I	2	5
9.	*Fallopia convolvulus* (L.) H. Löve	V	237	3	I	10	5
10.	*Spergula arvensis* L.	–	–	–	I	1	5
11.	*Matricaria maritima* L. *subsp.inodora* (L.) Dostal	I	6	5	II	931	1
12.	*Veronica persica* Poir.	V	503	1	I	5	5
13.	*Papaver rhoeas* L.	IV	347	2	–	–	–
14.	*Sinapis arvensis* L.	IV	191	3	I	1	5
15.	*Atriplex patula* L.	I	4	5	IV	504	1
16.	*Amaranthus retroflexus* L.	II	267	4	I	160	5
17.	*Lamium purpureum* L.	I	12	5	III	254	3
18.	*Thlaspi arvense* L.	I	38	5	–	–	–
19.	*Avena fatua* L.	IV	222	3	I	1	5
20.	*Anagalis arvensis* L.	I	5	5	I	4	5
21.	*Viola arvensis* Murray	I	5	5	I	4	5
22.	*Vicia hirsuta* (L.) S.F. Gray	I	2	5	I	1	5
23.	*Vicia tetrasperma* (L.) Schreb.	I	3	5	I	2	5
24.	*Vicia angustifolia* L.	I	2	5	I	1	5
25.	*Apera spica-venti* (L.) P.B.	I	1	5	I	1	5
26.	*Geranium pussilum* Burm. f. ex L	I	2	5	1	1	5
27.	*Centaurea cyanus* L.	I	1	5	–	–	–
28.	*Anthemis arvensis* L.	–	–	–	–	–	–
29.	*Veronica arvensis* L.	I	4	5	I	3	5
30.	*Sonchus asper* (L.) Hill.	I	2	5	I	1	5
31.	*Sonchus oleraceus* L.	I	1	5	–	–	–
32.	*Capsella bursapastoris* (L.) Medik.	I	2	5	–	–	–
33.	*Myosotis arvensis* (L.) Hill	I	2	5	I	2	5
34.	*Polygonum aviculare* L.	–	–	–	–	–	–
35.	*Galinsoga cilliata* (Raf.) S. F. Blake	–	–	–	–	–	–
36.	*Thlapsi arvense* L.	I	2	5	I	1	5
37.	*Erodium cicutarium* (L.) L'H.	I	1	5	I	1	5
38.	*Poa annua* L.	I	2	5	I	1	5
39.	*Senecio vulgaris* L.	–	–	–	–	–	–
40.	*Scleranthus annus* L.	–	–	–	–	–	–
41.	*Setaria viridis* (L.)P. Beauv.	I	2	5	I	2	5
42.	*Melandrium album* (Mill.) Garcke	–	–	–	–	–	–
43.	*Conyza canadensis* (L.) Cronquist	–	–	–	–	–	–

cont. table 6

1	2	3	4	5	6	7	8
Perenials							
44.	*Elymus repens* (L.) Gould	III	158	4	V	1119	1
45.	*Equisetum arvense* L.	I	20	5	IV	391	2
46.	*Convolvulus arvensis* L.	V	705	1	IV	305	2
47.	*Cirsium arvense* (L.) Scop.	II	136	4	I	46	5
48.	*Plantago maior* L.	I	2	5	I	2	5
49.	*Plantago lanceolata* L.	I	1	5	I	1	5
50.	*Taraxacum officinale* F.H. Wigg.	I	1	5	I	1	5
51.	*Rumex acetosella* L.	–	–	–	–	–	–
52.	*Trifolium repens* L.	I	1	5	I	1	5
53.	*Lotus corniculatus* L.	I	1	5	I	1	5
54.	*Trifolium arvense* L.	–	–	–	–	–	–
55.	*Artemisia campestris* L.	I	1	–	I	1	5

infested with *Convolulus arvensis* and *Elymus repens*. In the second period of the study (2014–2015) there was a decrease in the occurrence of *Stellaria media*, *Galium aparine* and *Sinapis arvensis* (5th degree of infestation), and a significant increase in the occurrence of *Matricaria maritima* ssp. *indora* (2nd degree of infestation). After 20 years the presence of *Papaver rhoeas*, *Thlaspi arvense*, *Avena fatua*, *Sonchus oleraceus* and *Capsella bursa-pastoris* was no longer observed. Among perennial taxa the frequency of *Convolvulus arvensis* and *Cirsium arvense* was lower, but there was an increase in infestation of the potato crops by *Elymus repens* (1st degree of infestation) and *Equisetum arvense* (3rd degree of infestation). *Plantago major*, *Plantago lanceolata*, *Taraxacum officinale*, *Trifolium repens*, *Lotus corniculatus* and *Artemisia campestris* occurred sporadically (5th degree of infestation). Overall in soil suitability complex 3 (defective wheat) a total of 45 taxa were recorded in the years 1991–1995, including 35 annuals and biennials and 10 perennial taxa and 40 dicotyledonous and 5 monocotyledonous taxa. In the second period of the study, conducted in 2014–2015, 41 taxa were counted (30 annuals and biennials and 11 perennial taxa; 36 dicotyledonous and 5 monocotyledonous taxa).

Good rye complex (5) in the first period of the study (1991–1995) was most heavily infested with *Chenopodium album*, *Echinochloa crus-galli* and *Stellaria media*, and additionally with *Galinsoga parviflora*, *Setaria pumila*, *Galium aparine*, *Galeopsis tetrahit*, *Polygonum persicaria*, *Fallopia convolvulus* and *Spergula arvensis* (Table 7). Among annuals and biennials taxa the highest infestation was caused by *Equisetum arvense*, *Convolvulus arvensis* and *Elymus repens*. In the second period of the study there was an increase

Table 7

A statement of the degree of phytosociological constancy (S), cover index (*D*) and the degree of an infestation (*Z*) of potato cultivation on defective wheat complex (3)

No.	Species	Years of study					
		1991–1995			2014–2015		
		S	*D*	*Z*	S	*D*	*Z*
1	2	3	4	5	6	7	8
Annuals and biennials							
1.	Stellaria media (L.) Vill.	IV	443	2	I	5	5
2.	*Chenopodium album* L.	V	610	1	V	1522	1
3.	*Echinochloa crus-galli* (L.) P. Beauv.	IV	841	1	III	1105	1
4.	*Galinsoga parviflora* Cav.	III	550	2	III	722	2
5.	*Setaria pumila* (Poir.) Roem. & Schutt.	III	400	3	III	554	2
6.	*Galium aparine* L.	III	63	5	I	10	5
7.	*Galeopsis tetrahit* L.	III	207	4	–	–	–
8.	*Polygonum persicaria* L.	III	34	5	II	86	5
9.	*Fallopia convolvulus* (L.) H. Löve	IV	152	3	I	6	5
10.	*Spergula arvensis* L.	III	451	3	–	–	–
11.	*Matricaria maritima* L. *subsp. inodora* (L.) Dostal	II	40	5	IV	1148	1
12.	*Veronica persica* Poir.	II	49	5	I	5	5
13.	*Papaver rhoeas* L.	I	33	5	I	2	5
14.	*Sinapis arvensis* L.	I	2	5	II	8	5
15.	*Atriplex patula* L.	II	14	5	III	512	2
16.	*Amaranthus retroflexus* L.	–	–	–	I	60	5
17.	*Lamium purpureum* L.	I	10	5	I	62	5
18.	*Thlaspi arvense* L.	I	20	5	II	31	5
19.	*Avena fatua* L.	I	3	5	–	–	–
20.	*Anagalis arvensis* L.	I	4	5	I	3	5
21.	*Viola arvensis* Murray	I	5	5	I	4	5
22.	*Vicia hirsuta* (L.) S.F. Gray	I	3	5	I	2	5
23.	*Vicia tetrasperma* (L.) Schreb.	I	3	5	I	2	5
24.	*Vicia angustifolia* L.	I	2	5	I	1	5
25.	*Apera spicaventi* (L.) P.B.	I	1	5	–	–	–
26.	*Geranium pussilum* Burm. f. ex L	I	2	5	I	1	5
27.	*Centaurea cyanus* L.	I	1	5	I	1	5
28.	*Anthemis arvensis* L.	I	2	5	I	2	5
29.	*Veronica arvensis* L.	I	4	5	I	3	5
30.	*Sonchus asper* (L.) Hill.	I	2	5	I	1	5
31.	*Sonchus oleraceus* L.	I	1	5	I	1	5
32.	*Capsella bursa-pastoris* (L.) Medik.	I	2	5	I	1	5
33.	*Myosotis arvensis* (L.) Hill	–	–	–	–	–	–
34.	*Polygonum aviculare* L.	I	2	5	I	2	5
35.	*Galinsoga cilliata* (Raf.) S. F. Blake	I	2	5	I	1	5
36.	*Thlapsi arvense* L.	I	1	5	I	1	5
37.	*Erodium cicutarium* (L.) L'H.	I	2	5	I	2	5
38.	*Poa annua* L.	I	2	5	I	1	5
39.	*Senecio vulgaris* L.	I	1	5	I	2	5
40.	*Scleranthus annus* L.	I	1	5	I	1	5
41.	*Setaria viridis* (L.)P. Beauv.	I	2	5	I	2	5
42.	*Melandrium album* (Mill.) Garcke	I	1	5	I	1	5
43.	*Conyza canadensis* (L.) Cronquist	I	1	5	I	1	5

cont. table 7

1	2	3	4	5	6	7	8
	Perenials						
44.	*Elymus repens* (L.) Gould	III	52	5	V	1506	1
45.	*Equisetum arvense* L.	IV	530	1	III	634	2
46.	*Convolvulus arvensis* L.	IV	331	2	II	205	4
47.	*Cirsium arvense* (L.) Scop.	II	125	4	I	102	5
48.	*Plantago maior* L.	I	2	5	I	2	5
49.	*Plantago lanceolata* L.	I	1	5	I	1	5
50.	*Taraxacum officinale* F.H. Wigg.	I	2	5	I	1	5
51.	*Rumex acetosella* L.	I	1	5	I	1	5
52.	*Trifolium repens* L.	I	1	5	I	1	5
53.	*Lotus corniculatus* L.	I	1	5	I	1	5
54.	*Trifolium arvense* L.	I	1	5	I	1	5
55.	*Artemisia campestris* L.	–	–	–	–	–	–

in the occurrence of *Galinsoga parviflora*, *Setaria pumila*, *Matricaria maritima* ssp. *indora* and *Atriplex patula* (all 1st degree of infestation), but *Galeopsis tertrahit*, *Spergula arvensis*, *Avena fatua* and *Apera spica-venti* were not present. Among perennial taxa there was a sharp increase in infestation with *Elymus repens*. Overall on soil suitability complex 5 (good rye) there were 52 weed taxa in 1991–1995, including 41 annuals and biennials and 11 perennial, and 47 dicotyledonous and 5 monocotyledonous. In the second period of the study, conducted in 2014–2015, 49 taxa were counted (38 annuals and biennials and 11 perennial; 46 dicotyledonous and 3 monocotyledonous). In general, irrespective of the soil complex, when the research was resumed after 20 years in selected municipalities of the Zamość region, certain taxa were no longer observed, such as *Papaver rhoeas* and *Avena fatua.* Moreover, the occurrence of *Galeopsis tetrahit*, *Veronica persica*, *Thlaspi arvense*, *Avena fatua*, *Centaurea cyanus*, *Sonchus oleraceus*, *Capsella bursa-pastoris*, *Sinapis arvensis*, *Spergula arvensis*, *Fallopia convolvulus* and *Polygonum persicaria* was very limited, and on poorer soil complexes *Galium aparine* and *Stellaria media* as well. On the other hand, an increase was noted in infestation of the potato crops by *Chenopodium album*, *Echinochloa crus-galli*, *Setaria pumila*, *Matricaria maritima* ssp. *indora*, *Atriplex patula* and *Lamium purpreum*. In addition, among perennial taxa the potato crops are currently infested to the greatest degree by *Elymus repens* and *Equisetum arvense*. As most of these species are nitrophilous, it seems that modern fertilization techniques involving higher levels of mineral fertilizers cause changes in infestation of potato crops, both indirectly (the forecrop) and directly.

Discussion

One of the most important factors affecting crop yield is weed infestation, and therefore the method of weed control is a significant element of cultivation techniques. In the case of potato, infestation at the start of the growing period (primary infestation) and at the end of this period (secondary infestation) is particularly harmful (RĘBARZ and BORÓWCZAK 2009). Secondary infestation developing when weed control procedures are no longer being applied poses a particular threat (SKRZYCZYŃSKA and SKRAJNA 2000). This results in accumulation of diasporas of weeds in the soil, which in subsequent crops are highly problematic for farmers and lead to increased costs associated with soil cultivation in neglected fields in subsequent growing seasons (MAŁECKA and BLECHARCZYK 2000, ZIEMIŃSKA-SMYK and TRĄBA 2004, KLIKOCKA 2010, WRZESIŃSKA et al. 2016).

Losses in potato yield due to weed infestation are mainly caused by the dominant taxa. Weeds considered very harmful include *Chenopodium album*, *Stellaria media*, *Galinsoga parviflora* and *Echinochloa crus-galli*. Other species are mentioned as well, such as *Galium aparine*, *Polygonum persicaria*, *Spergula arvensis*, *Convolvulus arvensis* and *Elymus repens* (ZARZECKA 2002, ZARZECKA and GUGAŁA 2005, JASTRZĘBSKI et al. 2015). These observations are confirmed by the present study. Studies dealing with this topic often identify species that are 'dominant' in the weed infestation, usually established arbitrarily by the author on the basis of abundance (BUJAK and FRANT 2006, KRASKA et al. 2006), or less often according to area cover (ŁABZA et al. 2003, GARGAŁA and TRĄBA 2014).

Weed infestation can also be evaluated using ecological indices (WANIC et al. 2005, 2006, 2016, ORZECH et al. 2016). According to ODUM (1982) species or groups of species which have a decisive effect on energy flow and the living environment of all other species are called ecological dominants. The degree of dominance of one, several or many species can be expressed by a suitable dominance index characterizing the importance of each species in the biocoenosis as a whole. The dominance index is the sum of squares of quotients of coefficients for each species (number of individuals, mass, production, etc.) and the sum of the coefficients. In the present study the dominance index was highest on the good wheat complex (0.116 in 1991–1995 and 0.141 in 2014–2015). On the remaining complexes the dominance index was much lower (by 18.5%). In the second period of the study, 2014–2015, the dominance index was higher than in 1991–1995, and was determined by the abundance of *Elymus repens* (0.024), *Chenopodium album* (0.021), *Echionochloa crus-galli* (0.015), *Stellaria media* (0.012) and *Matricaria maritima* subsp. *indora* (0.009). According to ODUM (1982) and SZOSZKIEWICZ et al. (1998), one of the

best ecological indicators is Shannon's total diversity index, which shows how much of the biocoenosis is comprised of species represented in low numbers and having a low coefficient of importance. A large number of species represented in small numbers has a pronounced effect on diversification of the species composition of individual trophic groups and entire biocoenoses. In the experiments Shannon's total diversity index was on average 0.663 and was highest on the good rye complex in the second period of the study (2014–2015) and on the good wheat complex in the first period of the study (1991–1995). A study by KLIKOCKA et al. (2010) showed that differences in soil cultivation methods and the use of catch crops in potato cultivation did not significantly differentiate the dominance index or Shannon's total diversity index.

Chenopodium album is a noxious weed in root crops with massive occurrence all over Poland (SKRZYCZYŃSKA et al. 2002, GARGAŁA and TRĄBA 2014). It may be present in a variety of environments, but is included among nitrophilous species preferring well-fertilized soils (DOBRZAŃSKI et al. 2002). In the area described in this study this species is a constant taxon on three of the soil complexes investigated and at the same time attains very high area cover, which increased considerably after 20 years of observations. Only on the good wheat complex was it noted at the same level as 20 years earlier. *Matricaria maritima* ssp. *indora* and *Echinochloa crus-galli* also occur frequently in fertile habitats and cover a large area. These are nitrophilous species included among expansive weeds not only in Poland, but in other European countries as well (KAPELUSZNY and HALINIARZ 2010, TRICHARD et al. 2013, RZYMOWSKA et al. 2015). This phenomenon was clearly evident in the present study, in which after 20 years a very pronounced increase was observed in the area cover of these species in the potato crops. Potato canopies, particularly near households, are heavily infested with *Galinsoga parviflora.* Its occurrence is linked to higher levels of organic fertilizer, human activity and zoochory (KAPELUSZNY and HALINIARZ 2010, TRZCIŃSKA-TACIK et al. 2010, ŁUGOWSKA and PAWLONKA 2016). It is a thermophilous species with a short growing period, and over the course of a year it can produce 2–3 generations and a vast number of seeds (even 300,000). It is most abundant in fresh, moist, moderately rich, warm soils with neutral pH (WNUK and ZIAJA 2010). *Galinsoga ciliata* was noted much less often and in a lesser degree in the study area.

Species of the grass family, particularly certain thermophilous monocots, are weeds posing a serious threat in infestation of root crops. An especially expansive taxon is *Echinochloa crus-galli*, one of the most widely distributed weeds in the world (SKRZYPCZAK and ADAMCZEWSKI 2002). In the Zamość region it is a species with massive occurrence on most root crop plantations, and its role has increased considerably in the last 20 years (KLIKOCKA and JUSZCZAK 2010). Another species in this group, *Setaria pumila*, makes up a somewhat

smaller portion of the weed infestation in this area, whereas *Setaria viridis* does not pose a threat to these crops. Among perennial weeds of the grass family the occurrence of *Elymus repens* is notable in the root crops of the area studied. This is a species which is also frequently observed in root crop plantations in other mesoregions of east-central and north-eastern Poland (SKRZYCZYŃSKA et al. 2002, RZYMOWSKA et al. 2015).

Among other perennial species, *Equisetum arvense* and *Convolvulus arvensis* played a major role, which is confirmed in a study on loess soils in the buffer zone of Roztocze National Park (ZIEMIŃSKA-SMYK and TRĄBA 2004). *Convolvulus arvensis* is one of the 15 major weeds in the world and in Poland. Its spread in root crops is due to its high competitiveness and resistance to herbicides. The large quantity of *Equisetum arvense* may indicate localized acidification of the soil (URBANOWICZ 2004). The soils of the area described in this study are largely more or less acidified.

On the basis of the study we can observe a simplification of the floristic composition and vegetation structure in the potato canopies in the Zamość region. Similar observations have been made in other regions of the country (GARGAŁA and TRĄBA 2014). Moreover, an impoverishment of calciphilous flora is observed in the Lublin Voivodeship (HALINIARZ and KAPELUSZNY 2014). This process is the result of the use of chemicals in crops, intensive mineral fertilization (especially with nitrogen), the use of certified seed, mechanization of field work, and a failure to apply proper crop rotation and organic fertilizers (RZYMOWSKA et al. 2015).

In the early 1970s it was already observed that segetal weeds accompanying crops were beginning to vanish. In recent decades many studies have been published on the changes taking place in the flora of fields as a result of intensive agriculture. In the 1990s a list of endangered weed species in Poland was compiled by WARCHOLIŃSKA (1994). It contained 100 species, which constitute a quarter of the weed flora in Poland. In the potato canopies studied in the Zamość region five of the species on this list were identified: *Spergula arvensis*, *Anagalis arvensis*, *Centaurea cyanus*, *Papaver rhoeas* and *Sinapis arvensis*.

Conclusions

1. The intensity of infestation and the floristic richness of the weed communities infesting root crops in the Zamość region were found to depend on habitat conditions. Overall 55 weed species were recorded (43 ephemeral and 12 perennial). The root crops were less infested on good and defective wheat complex soil than on good rye complex soil.

2. There were 45 to 52 species per relevé in the first period of the study (1991–1995) and 41 to 49 in the second period (2014–2015).

3. Nitrophilous species dominated in the potato crops: *Chenopodium album*, *Echinochloa crus-galli*, *Matricaria maritima* ssp. *inodora*, *Stellaria media*, *Galinsoga parviflora*, *Elymus repens* and *Equisetum arvense*.

4. Five taxa from the list of endangered species were noted: *Spergula arvensis*, *Anagalis arvensis*, *Centaurea cyanus*, *Papaver rhoeas* and *Sinapis arvensis*. When the research was resumed after 20 years, *Papaver rhoeas* and *Avena fatua* were not noted in the potato canopies of the Zamość region. However, the proportion of the following species increased in the infestation: *Chenopodium album*, *Echinochloa crus-galli*, *Setaria pumila*, *Matricaria maritima* ssp. *indora*, *Atriplex patula*, *Lamium purpreum*, *Elymus repens* and *Equisetum arvense*.

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EFFECT OF STORAGE TIME ON THE QUALITY OF JAPANESE QUAIL EGGS (*COTURNIX COTURNIX JAPONICA*)

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K e y w o r d s: quail, storage time, quality albumen, yolk, shell.

A b s t r a c t

Along with the storage time, in the egg content there occur changes based of which their quality and condition of egg freshness may be determined. The aim of the study was determination of the effect of 7-week storage period at a temperature of 4°C on the quality of Japanese quail eggs. The eggs were analyzed at one-week intervals to determine their morphological composition. No statistically significant differences were observed between particular dates of evaluation within the range of the egg weight and its proportional loss, which in the 7th week was 2.78%. No statistically significant differences were observed in the weight of yolk and albumen in total. The amount of albumen did not change, while the Haugh units ranged from 91.4 in the 1st week to 87.2 in the 7th week of storage. These results show that quail eggs are characterized by a long period of retaining freshness.

WPŁYW CZASU PRZECHOWYWANIA NA JAKOŚĆ JAJ PRZEPIÓRKI JAPOŃSKIEJ (*COTURNIX COTURNIX JAPONICA*)

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Abstrakt

Wraz z upływem czasu przechowywania jaj w ich treści zachodzą zmiany, na podstawie których można określić stan świeżości oraz jakość jaj. Celem pracy było określenie wpływu 7-tygodniowego przechowywania jaj przepiórki japońskiej w temperaturze 4°C na ich jakość. Jaja analizowano w odstępach tygodniowych, określając ich skład morfologiczny. Wykazano brak statystycznie istotnych różnic między poszczególnymi terminami oceny w obrębie masy jaja oraz procentowego jej ubytku, który w 7. tyg. przechowywania wyniósł 2,78%. Nie odnotowano statystycznie istotnych różnic w masie żółtka i białka ogółem. Wysokość białka się nie zmieniała, zaś jednostki Haugha przyjmowały wartości 91,4 w 1. tygodniu do 87,2 w 7. tygodniu przechowywania. Wyniki te pokazują, że jaja przepiórcze cechuje długi okres zachowania świeżości.

Introduction

Nowadays, we can observe an increasing consumer interest in food which has a directed and desirable effect on the body, the so called functional food. Good quality of such food and its beneficial effect on human health results from the presence of bioactive substances in its composition, stimulating the desirable effect of metabolic transformations (GÓRECKA et al. 2009). Therefore, quail eggs are becoming more and more popular as they fulfill the criteria of a product with traits of functional food. Quail eggs compared to chicken eggs, contain more essential exogenous amino acids, mineral compounds and elements such as iron, phosphorus, copper and zinc. They have a high content of vitamins, especially provitamin A, thiamine, riboflavine and cyanocobalamins. Owing to their chemical composition, they are not harmful for people allergic to albumen in chicken eggs. Moreover, quail eggs are characterized by a low cholesterol content and a more beneficial ratio of PUFA/SFA than chicken eggs (SINANOGLOU et al. 2011, GENCHEV 2012).

The quality of eggs of different bird species is conditioned by many genetic and environmental factors (TRAVEL et al. 2010), among others by the origin (genotype) of birds (CZAJA and GORNOWICZ 2006, LEWKO and GORNOWICZ 2007, SALMAN and TABEEKH 2011, DUKIĆ STOJČIĆ et al. 2012, GUGOŁEK et al. 2013), their age and stage of laying period (SAHIN et al. 2004, SEKER et al. 2004, CZAJA and GORNOWICZ 2006, KRAWCZYK 2009, NOWACZEWSKI et al. 2010 a,b) feeding methods (MILES and HENRY 2004, KORÉNEKOVA et al. 2007, YALČIN et al 2009, SULEYMAN and UYGUR 2010, SANGILIMADAN et al. 2012), housing system and prevention programs (VAN DEN BRAND et al. 2004, DE RUE et al. 2008, HIDALGO et al. 2008, DUKIĆ-STOJČIĆ et al. 2009), as well as environmental conditions of rearing, such as temperature and humidity, as well as the CO_2 content in the room (SAMLI et al. 2005, RAJI et al. 2009), methods of storing eggs (DUDUSOLA 2009) and conditions of their distribution.

For the consumer, especially significant are such quality traits of the egg as its size (weight) and freshness, to which testify, above all, height of thick

albumen, size of its surface area after breaking out and values of Haugh units, as well as the size of the air cell (ROBERTS 2004, DUDUSOLA 2009, GENCHEV 2012). In the formation of egg quality, a significant role is played by, among others, time and conditions of their storage, as eggs undergo the biological process of aging, which is initiated at the time of laying them. Intensity of changes occurring in the egg content during its storage is determined to a high degree by mechanical damage as well as the effect of external factors on eggs, such as temperature, humidity and sunlight. Eggs stored at a lower temperature, retain their freshness longer through inhibiting development of microflora. Storage temperature has a significant effect on the egg weight, albumen height, value of Haugh units, yolk index and size of the air cell (SAMLI et al. 2005, PIOTROWSKA 2010).

Owing to their specific structure and content of biologically active compounds, eggs belong to the most durable materials of animal origin (ROBERTS 2004). The basic structural element protecting the egg content against microbiological contamination is the shell along with outer and inner membranes and strong alkaline pH of the albumen, in which occur proteins of an antibacterial activity, ie. lysozyme, conalbumin and avidin (GOŁĄB and WAWRAS 2005, WĘSIERSKA 2006).

In order to retain good quality traits and complete usability as food, various forms of storage and conservation of eggs are used. Refrigeration is of greatest importance as it allows to maintain a high quality of eggs, while slowing down the ageing processes and reducing microflora development (JONES et al. 2004). Conducting measurements of physical and chemical changes occurring in the egg during the storage time allows to determine level of freshness, and thus its quality and culinary and technological value (CZARNIECKA-SKUBINA 2012). The aim of the research was determination of the effect of 7-week storage time on the quality of Japanese quail eggs, with a special consideration of traits, which the consumers and producers of eggs are interested in.

Materials and Methods

The research was carried out in the Department of Animal Science, Establishment of Poultry Breeding, of the Faculty of Animal Breeding and Biology, of the University of Science and Technology in Bydgoszcz, Poland. The experimental material included table eggs of Japanese quail, from the peak of the first laying period in birds. The eggs were obtained from layers in their 17. week of life, in their 10. week of laying. The flock had a population of 2000 birds.

The study included 210 eggs collected on the same day. The eggs were stored for between 1 and 7 weeks in a cooler at a temperature of 4°C. After 24

hours from laying, all eggs were weighed individually with the use of scales RADWAG WPS 360 C. In order to evaluate the effect of storage time on quality, in each week of storage 30 eggs were designated for the evaluation of the egg content.

The egg weight (g) was determined on a scales RADWAG WPS 360 C. Next, the egg content was broken out, and with the use of QCD system (TSS), the height of thick albumen and yolk (mm) was measured. With the use of a digital caliper, the yolk diameter was determined along chalaza lines, as well as the diameter of thick albumen (mm). The height of thick albumen (H) and the egg weight (W) allowed for calculating Haugh units according to the formula (WILLIAMS 1992): $HU=100 \lg (H + 7.7\text{-}1.7 W^{0,37})$. With the use of a pipette, two albumen fractions were separated from the egg content: a thick and a thin one. The yolk and then the thick albumen were weighed on scales WPS 360 C.

The eggshell after breaking out the content, was dried for an hour at a temperature 105°C in a laboratory dryer, type SUP 100 M. Next, on scales Medicat 160, shell weight [g/cm^3] was evaluated, while an electronic micrometer screw gauge was used to measure its thickness [mm]. Shell density was determined after separating a sample of about 1- to 2-grams with the use of a set for determining density of solids with the use of scales program, WPS 360 C. Distilled water, of a temperature of 17°C, was used as a standard liquid for determining shell density. Weight of thin albumen was calculated from the difference between the egg weight and the weight of yolk, thick albumen and shell. Proportional content of the yolk, thick albumen and thin albumen, as well as the shell was compared to the egg weight.

The evaluation of traits indicating the egg freshness did not include study of the depth of the air cell because of the pigmentation of eggshells, specific for this bird species. It is consistent with methodical assumptions of the studies carried out on quail eggs by other authors (DUDUSOLA 2009, DUKIĆ-STOJČIĆ et al. 2009, RAJI et al. 2009, NOWACZEWSKI et al. 2010a, NOWACZEWSKI et al. 2010b, SANGILIMADAN et al. 2012, JIN et al. 2011, SALMAN and TABEEKH 2011, GENCHEV 2012, LUKÁŠ et al. 2013).

The collected numerical data has been developed statistically with the use of STATISTICA PL (Statistika 2002), by ANOVA module. Mean values (x) of the studied traits and their variation coefficients (v) have been calculated. The significance of differences between the storage time of eggs have been verified by Sheffe test.

Results and Discussion

Basic indicators of physical and chemical changes occurring in the ageing process are the losses and diffusion of water and gases in the egg content, which cause, among other things, decrease in the egg volume and extension of the air cell, and thus decrease in the weight of the whole egg. While analyzing the mean egg weight (Table 1) it was found that seven weeks of storage did not significantly affect the variation of this trait. However, the proportional loss in the egg weight during storage increased with every week and was from 1.13% in the 2nd week to 2.78% in the 7th week of storage. Significant differences were observed between the first two weeks and the last one, which testified to the highest proportional weight loss in the final period of storage.

Table 1

Characteristics of the structure of quail eggs and their shells in successive weeks of storage

Storage Time (weeks)		Egg				Eggshell			
		weight [g]		weight loss		weight		thickness [mm]	density [g cm^{-3}]
		fresh egg	at the test time	[g]	[%]	[g]	[%]		
I	x	12.1^a	12.1^a	–	–	0.90^a	7.4^a	0.211^a	1.568^a
	v	5.8	5.8	–	–	13.3	10.8	9.6	9.3
II	x	11.8^a	11.7^a	0.13^b	1.13^b	1.00^a	8.6^a	0.245^a	1.541^a
	v	6.8	6.8	46.1	43.4	10.0	8.1	16.7	13.4
III	x	11.8^a	11.6^a	0.18^a	1.46^b	0.96^a	8.3^a	0.217^a	1.593^a
	v	5.9	5.2	55.6	54.8	7.3	6.0	4.2	11.2
IV	x	11.6^a	11.4^a	0.24^a	2.09^{ab}	0.88^a	7.8^a	0.208^a	1.549^a
	v	4.3	3.5	20.8	20.6	13.6	12.8	8.2	5.2
V	x	11.1^a	10.8^a	0.28^a	2.49^{ab}	0.86^a	7.9^a	0.217^a	1.348^a
	v	5.4	5.6	28.6	27.7	10.5	10.1	13.4	12.9
VI	x	11.9^a	11.6^a	0.31^a	2.65^{ab}	0.97^a	8.4^a	0.221^a	1.440^a
	v	9.2	10.3	35.5	38.6	8.2	10.7	18.6	9.2
VII	x	11.3^a	10.9^a	0.31^a	2.78^a	0.97^a	8.9^a	0.206^a	1.352^a
	v	7.1	7.3	19.4	19.1	7.2	5.6	7.8	14.1
Total	x	11.6	11.4	0.22	1.89	0.93	8.2	0.216	1.474
	v	6.9	7.0	59.1	58.7	10.8	11.0	12.0	12.3

$^{a, b}$ – mean values of the traits in columns in particular weeks of storage denoted by different letters differ significantly ($P = 0.05$)
x – standard value
v – coefficient of variation

Worse results were obtained by MORAES et al. (2009), in whose research, the weight loss in eggs stored at a temperature 7.5°C was on the 20th storage day 3.4%. It was probably the result of a higher by 3.5°C storage temperature, compared to the temperature of storing eggs in the author's own research.

During storage of quail eggs at a temperature of 13°C and humidity of 75–80% AYGUN and SERT (2013) observed egg weight loss of 1.72% after 7 days and 2.73% after 14 days. On the other hand, NOWACZEWSKI et al. (2010a), while comparing traits of fresh quail eggs with the ones stored for 3, 5 and 8 days (at a temperature of 19°C and relative moisture 50–55%), found that the egg weight decreased significantly from day 5 of storage. From other studies of this author (NOWACZEWSKI et al. 2010b), however, it follows that apart from thermal and moisture conditions, also the egg size has an influence on the weight losses in quail eggs during storage.

DUDUSOLA (2009), while using various storage techniques with quail eggs (at a room temperature, in a refrigerator, immersing in groundnut oil, storing in black polythene bag), observed the highest losses in the egg weight, both fresh ones and those stored for 4, 7, 14 and 21 days in the egg group kept at a room temperature, and the lowest in eggs subjected to several seconds of immersing in oil. AYGUN and SERT (2013) showed statistically significant differences in egg weight loss after sprinkling quail eggs from the control group with a 15% solution of propolis. A decrease in evaporation of water from 1.80% to 1.37% after the first week of storage, and from 2.74% to 2.28% was observed. CANER and YÜCEER (2015) showed that hen egg weight loss during a 6-week storage at a temperature of 24°C can be limited by covering the egg surface with shellac and zein. The authors recorded lower egg weight loss – 5.72% and 4.58% respectively – as compared to eggs not covered with any substance. Thus, from the quoted research it follows that apart from temperature and humidity, and their weight, also method of storage has an effect on the weight loss in eggs.

Similar tendencies concerning the formation of egg weight and its losses during storage with various methods (in a refrigerator at 5°C, at a room temperature of 21°C, as well as at a high temperature of 29°C), were observed by SAMLI et al. (2005) in chicken eggs, stored for 2, 5 and 10 days. From these studies it follows that in case of eggs stored in a refrigerator, at a temperature 5°C, no significant differences were found in the egg weight. However, along with an increase in temperature and storage time, losses in the egg weight significantly increased from 0.32 g (2nd day) to 0.65 g and 1.30 g, respectively on the 5th and 10th day of storage (temperature 21°C) and from 0.42 to 1.03 and 1.94 g (temperature 29°C).

Mineral compounds in the eggshell provide a long-term stability and mechanical resistance to deformation. It was confirmed in the results of the author's own research, which indicated that long-term storage of Japanese quail eggs at low temperatures had no visible effect ($P < 0.05$) on the shell weight, its thickness and density (Table 1). Different conclusions concerning the formation of the shell weight during storage of quail eggs were for-

mulated by NOWACZEWSKI et al. (2010 a) who found that shell weight decreased. These authors observed the lowest shell weight after 5 and 8 weeks of egg storage. These values significantly differed from the ones found in fresh eggs and those kept for 3 days. On the other hand, BAYLAN et al. (2011) proved that storage temperature to a slight degree affects shell thickness. However, quoted authors observed differences in the shell weight. During 45-day storage time at a temperature 4°C, a loss of approximately 0.14 g was observed, while at a temperature of 20°C, the weight loss was 0.20 g.

Egg albumen as a component of the highest weight in the structure of eggs is characterized by the most intensive physical and chemical changes, and processes occurring during the storage time. At first, there occurs a loss of water through evaporation via pores in the eggshell and via permeable membranes. The author's own research did not indicate any statistically significant differences within the weight of thick and thin albumen in total (Table 2). However, the weight of thick albumen decreased along with the extension of the eggs' storage time from 2.6 g to 1.6 g, although these differences were mostly not confirmed statistically, apart from the value of this trait in eggs stored for 7 weeks. Different results were indicated by

Table 2

Traits of the yolk and albumen in quail eggs in successive weeks of storage

Storage Time (weeks)		Weight [g]				Diameter [mm]		Height [mm]		Haugh units [HU]
		yolk	albumen			yolk	thick albumen	yolk	thick albumen	
			thick	thin	total					
I	*x*	3.6^{a}	2.6^{a}	5.0^{a}	7.6^{a}	25.8^{a}	48.0^{a}	12.3^{a}	4.9^{a}	91.4^{a}
	v	5.6	19.2	16.0	6.6	5.4	10.2	6.5	16.3	5.3
II	*x*	3.3^{a}	2.6^{a}	4.8^{a}	7.4^{a}	24.9^{ab}	42.3^{ab}	11.4^{a}	5.1^{a}	92.6^{a}
	v	9.1	23.1	16.7	6.8	4.8	10.4	6.1	13.7	4.2
III	*x*	3.4^{a}	2.5^{a}	4.7^{a}	7.2^{a}	24.1^{ab}	40.3^{b}	12.2^{a}	4.8^{a}	91.1^{a}
	v	8.8	20.0	10.6	5.6	2.1	4.2	4.9	6.3	1.8
IV	*x*	3.4^{a}	2.4^{a}	4.7^{a}	7.1^{a}	24.1^{ab}	38.7^{b}	11.8^{a}	4.4^{a}	89.0^{a}
	v	11.8	29.2	14.9	4.2	4.1	7.0	9.3	9.1	2.8
V	*x*	3.3^{a}	1.9^{a}	4.8^{a}	6.7^{a}	23.1^{b}	36.1^{b}	12.1^{a}	4.1^{a}	87.9^{a}
	v	11.8	15.8	10.4	6.0	5.6	4.4	2.5	30.0	6.1
VI	*x*	3.7^{a}	2.0^{a}	5.0^{a}	7.0^{a}	23.4^{b}	37.0^{b}	11.8^{a}	4.1^{a}	87.2^{a}
	v	10.8	15.0	16.0	11.4	5.1	7.3	5.1	7.3	1.8
VII	*x*	3.3^{a}	1.6^{b}	5.0^{a}	6.6^{a}	23.0^{b}	36.5^{b}	11.5^{a}	4.0^{a}	87.2^{a}
	v	9.1	12.5	14.0	9.1	4.3	4.4	5.2	12.5	3.6
Total	*x*	3.4	2.2	4.9	7.1	23.9	39.5	11.9	4.4	89.2
	v	8.8	27.3	14.3	8.5	5.9	12.2	5.9	15.9	4.4

$^{a, b}$ – mean values of the traits in columns in particular weeks of storage denoted by different letters differ significantly ($P = 0.05$).

x – standard value

v – coefficient of variation

NOWACZEWSKI et al. (2010 a). The authors found statistically confirmed differences in the albumen weight already after 3 days of storing quail eggs. In their studies on hen eggs SCOTT and SILVERSIDES (2000) observed statistical differences in the weight of albumen after the 5th and 10th day of storage, respectively 1 g and 1.49 g.

Following the loss of water and carbon dioxide from the egg albumen there occurs thinning of its thick fraction, which is characteristic of the advanced ageing process in the egg. In the author's own research, no significant differences were indicated in the height of thick albumen (Table 2). Values of Haugh units were from 91.4 in the 1st week to 87.2 in the 7th week of storage, which may testify to retaining freshness in eggs. From the studies of other authors (DUDUSOLA 2009, NOWACZEWSKI et al. 2010b). It follows that worse results are obtained while storing eggs at higher temperatures. This is also confirmed by the research carried out on chicken eggs by SAMLI et al. (2005), in which they observed a significant deterioration of the albumen quality along with an increase in temperature and time of egg storage. Quoted authors observed a decrease in the value of HU from 91.4 to 76.3 at a temperature 5°C for 10 days of storage, while at a temperature 21°C and 29°C HU values decreased to 53.7 and 40.6 respectively. Lower albumen quality in eggs stored at higher temperature than in the refrigerator, at a temperature 15.5°C, is confirmed in the studies also carried out on chicken eggs by MILES and HENRY (2004).

NOWACZEWSKI et al. (2010b) during a one-week storage of quail eggs at a temperature 15°C, observed a decrease in Haugh units by 6.5, compared to the initial state, being 86 HU. On the other hand, DUDUSOLA (2009), while using various methods of storing quail eggs, found the highest values of Haugh units (62.1 to 58.4) in eggs kept in a refrigerator and the lowest (53.8 to 57.4) in the group of eggs stored at a room temperature. HU values in eggs stored with all four methods (at a room temperature, in a refrigerator, immersing in groundnut oil, storing in black polythene bag) decreased along with an extension of storage time. Only statistically confirmed differences between 4-day and 7-day egg storage at a room temperature and in the refrigerator were not indicated.

The final protective barrier in the layer structure of the egg is vitelline membrane, which gives shape to the yolk and maintains diffusive balance between albumen and yolk. During long-term egg storage, water from the albumen may diffuse through vitelline membrane to the yolk, increasing its volume. In the author's own research, no statistically significant differences were indicated in the yolk weight between successive evaluation dates. This is confirmed by the research of NOWACZEWSKI et al. (2010 a), in which it was also proved that time of storing quail eggs did not affect the yolk weight. From

other studies of this author (NOWACZEWSKI et al. 2010 b), it follows that apart from the duration of storage time, also the egg size has an effect on the proportional share of yolk. Quoted authors observed that in case of storing eggs both for 3 and 5 days, quail eggs of a higher weight (> 12.51 g) were characterized by a higher proportion of yolk, by approximately: 2.3 and 1.5%, respectively, than lighter eggs (to 10.50 g and from 10.51 –11.50 g). However, according to MORAES et al. (2009), duration of storage time does not significantly affect the proportional share of the egg yolk.

Conclusion and Applications

1. Analysis of changes occurring in quail eggs during 7-week storage indicated lack of significant differences between particular dates of evaluation in the egg weight. Significant differences in the proportional weight losses were observed only between the first three and the last week of egg storage.

2. During the 7-week period included in the studies, no statistically significant differences were observed in the weight of yolk and thick and thin albumen in total. Invariable height of thick albumen and high values of Haugh units during the whole storing period testified to the retention of high albumen quality in eggs.

3. These results allow to state that quail eggs are characterized by a relatively long period of retaining freshness, and their 7-week storage does not affect quality deterioration, and consequently their culinary and technological value.

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VARIATION IN EGG QUALITY TRAITS DEPENDING ON STORAGE CONDITIONS

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K e y w o r d s: table egg, storage time, quality yolk, albumen, shell.

A b s t r a c t

The aim of the study was determination of changes in quality traits of eggs depending on storage conditions. The study material were 360 table eggs laid by 52 weeks of age laying hens, Tetra SL, being in their peak of egg production. The eggs were stored at a temperature of 4 and 23°C. Evaluation of egg quality was carried out on the 1st, 7th, 14th, 21st, and 28th day, analyzing 40 eggs from each group. It was found that storage conditions had a significant effect on the loss of egg weight and thick albumen as well as on an increase in its pH value. Temperature of 23°C had a greater effect on the dynamics of these changes, while eggs stored at a temperature of 4°C even after 28-day storage were characterized by a good quality and freshness. Long-term storage had no significant effect on the shell weight, its thickness and elastic deformation and resistance to crushing.

ZMIENNOŚĆ CECH JAKOŚCIOWYCH JAJ W ZALEŻNOŚCI OD WARUNKÓW PRZECHOWYWANIA

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Abstrakt

Celem badań było określenie zmian cech jakościowych jaj w zależności od warunków przechowywania. Materiał badawczy stanowiło 360 jaj konsumpcyjnych zniesionych przez 52-tygodniowe kury nieśne Tetra SL będące w szczycie nieśności. Jaja przechowywano w temperaturze 4 i 23°C. Ocenę jakości jaj przeprowadzano w 1., 7., 14., 21., i 28. dniu, analizując po 40 jaj z każdej grupy. Stwierdzono, że warunki przechowywania miały istotny wpływ na ubytek masy jaja i białka gęstego oraz zwiększenie wartości pH. Temperatura 23°C miała większy wpływ na dynamikę tych zmian, natomiast jaja przechowywane w temperaturze 4°C nawet po 28-dniowym przechowywaniu cechowały się dobrą jakością i świeżością. Długoterminowe przechowywanie nie miało istotnego wpływu na masę skorupy, jej grubość oraz elastyczne odkształcenie i wytrzymałość na zgniecenie.

Introduction

Egg quality is conditional on many genetic and environmental factors, among other things bird's origin, its age and stage of egg production period (BASMACIOGLU and ERGUL 2005, TRAVEL et al. 2010, KRAWCZYK 2009, CALIK 2011, GUGOŁEK et. al. 2013). Moreover, formation of quality traits of egg content and shell is also affected by nutrition, housing system and environmental conditions of rearing, i.e. temperature and humidity as well as CO_2 content in buildings (DE RUE et al. 2008, BIESIADA-DRZAZGA and JANOCHA 2009).

The requirements for the commercial quality of table eggs are presented in the PN-A-86503/AZ1 standard. The most important quality trait of table eggs is their freshness condition, evaluated, among other things, based on the degree of thinning of albumen, pH value and size of the air cell (CAMPO et al. 2000, HALAJ et al. 2000, KRAWCZYK and CALIK 2006). Intensity of changes during egg storage is caused largely by mechanical damage and the effect of temperature, humidity and sunlight. Under PN-A-8650: 1998 eggs should be stored in a clean and dry warehouse at the temperature of 8 to 13°C. During storage eggs should also be protected against weather conditions. The requirements for storage of eggs presented in the standard are met most frequently in egg warehouses. However, the majority of points of sale do not meet the requirements for the correct storage of eggs. Egg storage leads to decrease in its nutritive value and culinary and processing usefulness (RIZK et al. 2001, SILVERSIDES and BUDGELL 2004).

The aim of the studies was determination of changes in quality traits of eggs depending on their storage conditions.

Methods

Research material were 360 table eggs laid by 52 weeks of age laying hens, Tetra SL, in their peak of egg production period. The hens were kept in the cage system, according to the Council Directive 99/74/WE of 19 July 1999, which established their minimum welfare. The birds were fed *ad libitum* with a standard mixture for layers according to the obliging recommendations (LEESON and SUMMERS 2005).

In order to evaluate variation in quality traits of eggs depending on storage conditions, half of the eggs were stored at a temperature of 4°C, and the second half at 23°C and relative humidity of 45–50%. The evaluation of egg quality was carried out on the 1st, 7th, 14th, 21st, and 28th day of storage, evaluating 36 eggs from each group, taking into consideration the weight of: egg [g], yolk [g] and albumen divided into a thick and thin fraction [g]. Elastic deformation of shell was tested [μm cm^{-2}] with the use of an N.V. Marius-Utrecht device, as well as its resistance to crushing [kg cm^{-2}] with the use of Egg Force Reader™ manufactured by Orka Food Technology Ltd. pH value of yolk and albumen was determined with the use of pH-meter Elmetron CP-411. With the use of QCD apparatus from TSS, height of thick albumen was measured [mm], which along with egg weight (W) allowed to calculate Haugh units [HU] according to the formula (WILLIAMS 1992): $HU = 100 \log (H + 7.57\text{-}1.7\ W^{0.37})$.

Thick albumen was isolated by removing thin albumen with a glass pipette. Inner thin albumen was removed by cutting thick albumen. The weight of thin albumen in the egg was determined by subtracting the weight of yolk, albumen and dried shell from the total weight of the egg. For this reason, the number of eggs with damaged thick albumen was not determined. The above activities were repeated on set dates of egg quality assessment. Thin albumen created as a result of hydration of thick albumen caused by storage was also removed. Eggshells were dried for three hours at a temperature of 105°C in a dryer SUP 100 M. Next, shell weight was evaluated [g] as well as its thickness [mm] at theequator of the egg with the use of an electronic micrometer screw.

Obtained results were subjected to analysis of variance, and significance of differences was determined with Duncan's test, with the use of a statistical package SAS Enterprise Guide 4.3.

Results

Table 1 presents mean egg weight depending on temperature (4 and 23°C) and on the storage time (1st, 7th, 14th, 21st, 28th day). Egg weight loss was observed on all days of evaluation, irrespective of storage conditions.

The biggest loss was observed after 28 days of storage at 23°C. However, the differences between the initial and final egg weight were not statistically significant. Percentage of weight loss in eggs during storage increased significantly ($P < 0.001$), at a temperature of 4°C by: 0.64%; 1.30%; 1.61%; 2.12%, respectively and by 2.11%; 3.58%; 5.73%; 7.97% at a temperature of 23°C.

While storing eggs at a temperature of 23°C, significant differences were indicated ($P < 0.001$) within the thick albumen weight and HU (Table 2). Irrespective of the temperature of storage it was observed that after 28 days

Table 1

Quality traits of eggs during storage depending on temperature

Temp.	The period of storage	Number of eggs [pcs]	Weight [g]					Proportion per egg [%]		
			eggs		shell	yolk	albumen	shell	yolk	albumen
			"0"	on the day of testing						
4°C	1	36	63.48	.	5.87	17.13	40.47	9.27	27.10	63.63^{a}
	7	36	62.84	62.44	5.88	17.21	39.35	9.46	27.69	62.85^{ab}
	14	36	63.57	62.76	5.85	17.17	39.74	9.36	27.53	63.11^{ab}
	21	36	63.17	62.16	5.99	17.04	39.13	9.65	27.57	62.78^{ab}
	28	36	62.99	61.66	5.92	17.37	38.37	9.64	28.22	62.14^{b}
23°C	1	36	63.48	.	5.87	17.13	40.47^{a}	9.27^{b}	27.10^{c}	63.63^{a}
	7	36	62.90	61.57	5.79	17.02	38.76^{ab}	9.46^{b}	27.69^{c}	61.53^{b}
	14	36	62.89	60.65	5.98	16.85	37.83^{ab}	9.95^{a}	27.99^{c}	59.85^{c}
	21	36	63.65	60.02	6.12	17.46	36.44^{bc}	10.23^{a}	29.29^{b}	57.02^{d}
	28	36	63.70	58.63	5.91	17.88	34.84^{c}	10.12^{a}	30.65^{a}	54.51^{e}

$^{a, b, c}$ – mean trait values in columns in particular weeks of storage denoted with different letters differ statistically significantly ($p \leq 0.05$)

Table 2

Quality traits of albumen depending on storage conditions

Temp.	Day of analysis	Number of eggs [pcs]	Thick albumen weight		Albumen height [mm]	Haugh units	pH
			[g]	[%]			
4°C	1	36	21.46^{a}	33.95^{a}	5.75	72.27	7.54^{d}
	7	36	19.92^{ab}	31.85^{b}	5.42	70.71	7.90^{c}
	14	36	18.26^{b}	29.05^{c}	5.73	72.72	8.05^{b}
	21	36	19.66^{b}	31.54^{b}	5.49	70.67	8.22^{a}
	28	36	18.55^{b}	30.07^{bc}	5.56	71.60	8.26^{a}
23°C	1	36	21.46^{a}	33.95^{a}	5.75^{a}	72.27^{a}	7.54^{c}
	7	36	19.60^{b}	31.57^{b}	4.24^{b}	59.48^{b}	8.31^{b}
	14	36	14.91^{c}	24.67^{c}	2.89^{c}	39.56^{c}	8.56^{a}
	21	36	7.85^{d}	13.19^{d}	2.57^{cd}	36.12^{c}	8.52^{a}
	28	36	5.27^{e}	9.12^{e}	2.28^{d}	32.66^{c}	8.54^{a}

$^{a, b, c}$ – mean trait values in columns in particular weeks of storage denoted with different letters differ statistically significantly ($p \leq 0.05$)

the weight of albumen decreased significantly statistically. In the group of eggs stored at 23°C, there was a decrease in the weight of albumen by 9.12% as compared to the weight in a fresh egg. In the group with eggs where the temperature was maintained at the level of 4°C, there was a 1.49% decrease in the weight of albumen.

Temperature and storage time resulted in a change in the percentage share of yolk in the egg weight. Mean percentage share of yolk per egg during storage at 23°C increased statistically significantly by 3.55%.

Time of the storing eggs had a significant ($P < 0.001$) effect on pH value of albumen.

In both groups an increase in the pH value was observed, with accelerated dynamics of changes at a temperature of 23°C. Irrespective of the temperature of the environment, the largest increase in albumen pH was observed during the first 14 days of storage.

Long-term storage of eggs at a temperature of 4 and 23°C had no visible effect on the shell weight, its thickness, elastic deformation [μm cm^{-2}] or resistance to crushing [kg cm^{-2}]. In the whole storage period, resistance to breakage under pressure of 500 g was normal and amounted to: at a temperature of 4°C (24.11; 23.78; 25.08; 23.93; 23.32 μm, respectively) and at 23°C (24.21; 23.18; 22.36; 23.10; 24.26 μm, respectively). The lowest force causing shell breakage on the 1st and 28th day of study was: 3.18 kg and 3.17 kg (at a temperature of 4°C) and 3.18 and 3.10 kg (at a temperature of 23°C), respectively.

At a higher storage temperature, significant differences were indicated in the percentage of shell per egg between 1st–7th and 14th–28th day of evaluation, which is connected with a high water loss from the egg content.

Discussion

In our own studies an intensive decrease in egg weight was observed in the group of eggs stored at a temperature of 23°C. Similar results were observed by GAVRI and USTUROI in their studies (2012). They suggested that more significant variations in egg weight within the 35 days of storage occurred in the egg group stored at a temperature of 20–25°C (4.18 g) than in those stored at the temperature of 4°C (1.05 g). While analyzing the effect of storage on variation in egg weight Jin et al. (2011) found that this trait did not change significantly during the 10-day storage period at a temperature of 5 and 21°C. Significant variations started at 29°C.

According to JIN et al. (2011) the percentage of egg weight loss significantly decreased along with an increase in temperature and storage time. Increasing storage temperature up to 29°C, caused increase in the loss of egg weight by

1.74 and 3.67%, on the 5th and 10th day of storage, respectively. These results correspond to the studies of SAMLI et al. (2005), who indicated a significant ($P < 0.001$) proportional loss of egg weight of 2.08 and 3.11%, during 5 and 10 days of storage, respectively, at a temperature of 29°C. Loss in egg weight given by AKYUREK and OKUR (2009) was also similar. Loss in the egg weight is connected with the loss of water, carbon dioxide, ammonia and hydrogen sulphide, which are produced as a result of an enzymatic breakdown of proteins and fats in the egg content (ALSOBAYEL and ALBADRY 2011, JIN et al. 2011). Dynamics of these processes increases along with an increase in temperature, therefore a lower loss in the egg weight is found in case of refrigeration, and a higher one at a room temperature.

In the evaluation of the egg content freshness, the most important indicator is quality of albumen, which should contain a large proportion of thick fraction (SCOTT and SILVERSIDES 2000). Our own studies and those of other authors (HALAJ et al. 2000, PAVLOWSKI et al. 2000, NIEMIEC et al. 2001, CALIK 2013) confirm that while storing eggs at a higher temperature, albumen structure undergoes a change through its thinning and increase in pH, whereas after breaking it, it is difficult to distinguish particular fractions in its content. Thinning of the thick albumen fraction occurs as a result of alkalisation of lysozyme complex with ovomucid. It results in a decline of interactions between proteins (TRZISZKA 2000).

The weight of thick albumen and yolk also prove lower quality and thinning of albumen. It was observed in our own studies that prolongation of the period of storage was accompanied by a decrease in thick albumen weight and an increase in yolk weight (TRZISZKA 2000).The change in the proportion of particular elements of the egg content during storage suggests diffusion of water from albumen through the vitelline membrane into the yolk, which results in a decrease in albumen weight and an increase in the volume of yolk. It was also confirmed in the studies of other authors (SCOTT and SILVERSIDES 2000, CALIK 2011, JINET al. 2011). During storage of eggs (10–21 days) at different temperatures (5–21°C) there occurred an increase in the weight of yolk per egg from 0.56% to 4.12%.

A decrease in the value of the HU units in our own studies was connected with the temperature of air because a significant decrease in the value was observed only in the group of eggs stored at a temperature of 23°C. Similar relationship was observed by JIN et al. (2011) who noted that only at a temperature of 21 and 29°C the values of HU decreased, whereas no decrease was observed at a temperature of 5°C, which was in contrast with the results of JONES and MUSGROVE (2005) who at the temperature 4°C observed a decrease in the HU value from 82.59 to 67.43 in the 10th week of storage. Whereas TAYEB (2012) writes that during storage at a temperature of 20°C, the HU units

decreased from 72.68 to 52.11.These results correspond with other studies (TONA et al. 2004, KEENER et al. 2006, AKYURET and OKUR 2009, RAJI et al. 2009), which proved a negative effect of storage on the HU value.

In our own studies it was observed that, irrespective of the temperature, there was an increase in the pH value of the egg content. Our results are in accordance with the data presented by other authors (SCOTT and SILVERSIDES 2000, SAMLI et al. 2005, AKYUREL and OKUR 2009, JIN et al. 2012, CALIK 2013) who observed in their studies variations in the pH value within the range of 7.34 and 9.77. In the cited studies, the time of storage resulted in an increase in the pH value of albumen (OKUR 2009, JIN et al. 2012, CALIK 2013). According to CALIK (2013), the optimum pH of albumen ranges from 7.5 to 8.00. At higher pH values there occur series of adverse changes in the egg content: shrinkage of ovomucin and shifting of the yolk.

Lack of changes in physical characteristics and the shell weight during storage suggest that mineral compounds contained in the eggshell provide a long-term stability and mechanical resistance to deformation. This was confirmed by the obtained results which showed that a long-term storage of eggs at a temperature of 4°C and 23°C had no influence on the weight of shell, its thickness or elastic deformation [μm], as well as on resistance to crushing [kg cm^{-2}]. Similar results were obtained by JONES and MUSGROVE (2005). Both in our own and in the studies of the authors mentioned above only a percentage increase in the egg tightness was observed during storage. These results correspond with the data presented by other researchers (SCOTT and SILVERSIDES 2000, TAYEB 2012) who observed the effect of the time of storage on the percentage share of the shell in egg.

Conclusions

In conclusion, it was found that storage conditions had a significant effect on the loss in egg weight and in thick albumen as well as on an increase in pH value. All changes related to the storage of eggs contribute to a gradual loss of freshness, thus its culinary and processing usefulness. Temperature of 23°C had an unfavorable effect on the dynamics of changes occurring in the egg storage, while at a temperature of 4°C even after 28-day storage, they were characterized by a good quality and freshness.

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WILDLIFE – VEHICLE COLLISIONS IN URBAN AREA IN RELATION TO THE BEHAVIOUR AND DENSITY OF MAMMALS

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K e y w o r d s: urban roads, vehicle collisions, wild animals, GIS.

A b s t r a c t

The aim of the study was to characterise the problem of road accidents involving selected species of wild-living animals present in the area of Lublin. Another aim of the investigations was to determine the relationship between selected behavioural elements of the annual life cycle of animals and the incidence of wildlife-vehicle collisions. The information about wildlife-vehicle collisions was obtained from the documentation held by the shelter for homeless animals in Lublin and veterinary services. The data are presented in a spreadsheet and analysis was performed in the GIS (ArcGIS 10.1) environment. Based on the ESRI Base Map-BING MAP HYBRYD, a vector database of streets where the incidents had taken place was compiled. Each street was assigned the number of incidents recorded in the period of 2009–2012. Animals were divided into three groups: large mammals, small mammals and bats. The compiled data indicate the highest road mortality among roe deer (132), foxes (63), and martens (33). The reported results show the greatest number of wildlife-vehicle collisions on exit roads leading from the city centre. Presumably, this may be associated with the lack of speed limits and possible faults in the infrastructure arising already at the design stage.

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WYPADKI DROGOWE ZE ZWIERZĘTAMI DZIKIMI NA OBSZARACH MIEJSKICH W ZALEŻNOŚCI OD ICH BEHAWIORU I ZAGĘSZCZENIA

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S ł o w a k l u c z o w e: drogi miejskie, zdarzenia drogowe, zwierzęta dzikie, GIS.

A b s t r a k t

Celem pracy było scharakteryzowanie wypadków drogowych z udziałem wybranych gatunków zwierząt wolno żyjących, bytujących na terenie Lublina. Wykazano zależności między wybranymi elementami behawioralnymi rocznego cyklu życiowego zwierząt a częstotliwością występowania kolizji drogowych z ich udziałem. Informacje o wypadkach drogowych z udziałem zwierząt dzikich uzyskano z dokumentacji schroniska dla bezdomnych zwierząt w Lublinie oraz od służb weterynaryjnych. Dane zestawiono w arkuszu kalkulacyjnym oraz w środowisku GIS (ArcGIS 10.1). Na podstawie ESRI Base Mape-BING MAP HYBRYD przygotowano wektorową bazę danych ulic, których dotyczyły zdarzenia. Każdej ulicy przypisano liczbę zdarzeń zarejestrowanych w latach 2009–2012. Zwierzęta podzielono również na trzy grupy: duże ssaki, małe ssaki oraz nietoperze. Uzyskane dane wskazują, że najwyższa śmiertelność na drogach wśród zwierzyny dotyczyła saren (132), lisów (63) oraz kun (33). Na podstawie uzyskanych wyników można stwierdzić, że najwięcej wypadków wydarzyło się na drogach wylotowych z centrum miasta. Należy sądzić, że związane jest to z brakiem ograniczenia prędkości oraz możliwymi błędami w infrastrukturze już na etapie projektowania.

Introduction

Due to the intensive development of motorisation, transport routes are being continuously modernised, new expressways are being built, and the network of dual carriageways and motorways is being expanded. All these investments are aimed at improvement of the comfort of travelling and enhancement of the efficiency of road transport. However, the developing road infrastructure undoubtedly interferes with the natural habitat of animals. Fragmentation of biotopes by transport routes increases the risk of wildlife-vehicle collisions and accidents (JĘDRZEJEWSKI at al. 2006).

Besides linear infrastructure and intensification of agriculture, other types of human activity, e.g. residential developments, land reclamation, and drainage of wetlands cause similar transformations and loss of animal habitats. Housing development is a factor that limits the surface area of habitats inhabited by wild animals, which have to change their living environment completely. This is especially evident on the outskirts of intensively expanding cities and towns. Synurbic species can be found in an urbanised landscape

more frequently. The occurrence of foxes and wild boars in close proximity to human settlements was a rarity several years ago but is nowadays common, also in urban areas. The ease of finding food and absence of natural enemies in the urbanised landscape exerts a considerable impact on the functioning of populations of these species in such different living conditions. This creates dangerous situations for both animals and humans (collisions with vehicles, noise or light stress, possibility of contracting diseases from domestic or livestock animals) (KLIMASZEWSKI 2011, MILCZAREK 1993). In addition, shrinking natural habitats and the increasing number of wild animals makes the move to areas where never before occurred In particular species which can travel long distances, therefore, they may be a vector that plays an important role in parasite transmission in the natural environment. Infections new species of parasites are very dangerous phenomenon which can lead to falls a large number of animals (BURLINSKI at al. 2011). The problem may be invasive species spread with human activity and posing a threat to already present fauna eg. american mink, raccoon dog, raccoon (GUGOŁEK at al. 2014).

The aim of the study was to characterise the problem of road accidents involving selected species of wild-living animals present in the area of Lublin. Another aim of the investigations was to determine the relationship between selected behavioural elements of the annual life cycle of animals and the incidence of wildlife-vehicle collisions.

Materials and Methods

Investigations of animal road casualties are difficult methodically and logistically. In Poland, many collisions are not reported and only fragmentary information about this type of incidents has been gathered by various institutions, e.g. national parks, forestry offices, and hunter associations. The police and institutions that arrive directly to the scene of a collision possess the most complete data. The information about wildlife-vehicle collisions was obtained from the documentation held by the shelter for homeless animals in Lublin and veterinary services. The data were available in the form of a paper notebook with tables presenting the animal species and the name of the street. Only a few records had an exactly specified address (80 cases of the total 930). The data from 2009–2012 were obtained from the veterinary clinic staff and those from 2011–2012 were provided by the animal shelter.

The data are presented in a spreadsheet containing the following fields: street name, animal species, number of incidents, and date of the incident. Further analysis was performed in the GIS (ArcGIS 10.1) environment. Based on the ESRI Base Map-BING MAP HYBRYD, a vector database of streets

where the incidents had taken place was compiled. Each street was assigned the number of incidents recorded in the period of 2009–2012. According to the number-of-incidents attribute, the streets were categorised in the form of a map. Red colour indicated streets with the highest number of incidents and a colour scale was used for the number of incidents assigned to each street (e.g. red – 27 incidents in one street; *n* – number of streets with 27 incidents). The lack of data on the exact localisation of incidents prevented compilation of a more detailed study.

Animals were divided into three groups: large mammals (mainly roe deer (*Capreolus capreolus*) and smaller numbers of red deer (*Cervus elaphus*) and wild boar (*Sus scrofa*), small mammals (fox (*Vulpes vulpes*), marten (*Martes foina*), and others), and bats. The grouping followed the different behaviour patterns of the species and the periods of an increased number of collisions with animals from each group.

Results and Discussion

In 2009–2012, 930 wildlife-vehicle collisions were reported in the area of Lublin. Given the aim of the investigations, the results did not include data concerning dogs, cats, and pigeons.

The compiled data indicate the highest road mortality among roe deer (132), foxes (63), and martens (33). The proportion of other species was inconsiderable. These data confirm the information provided by other studies, which reported the greatest number of wildlife-vehicle collisions, i.e. ca. 75%, with roe deer (SAENZ DE SANTA MARIA and TELLERIA 2015, TAJCHMAN at al. 2010). This is most probably determined by two factors. The first one is related to the dynamic growth of the population of this species, estimated at ca. 50% of the initial number over the last decade (BUDNY at al. 2010). The other factor is, undoubtedly, the behaviour of this species consisting in long-distance migrations (KLIMASZEWSKI 2011). Field data from the area of Poland confirm the highest proportion of roe deer and wild boars involved in wildlife-vehicle collisions; the national data additionally include deer in this group (CZERNIAK and TYBURSKI 2011). Within the Lublin city limits, the number of killed deer (14 individuals) and wild boars (3 individuals) was relatively low.

The analysis of the changes in the mean number of incidents with large mammals (Table 1, Figure 1) shows two periods characterised by an increase in wildlife-vehicle collisions, i.e. spring (May) and winter (December and January). In this group of animals, roe deer account for 97%, which in the spring period can be explained by the enhanced activity of roebucks establishing and protecting their territory (PIELOWSKI 1999, TAJCHMAN at al. 2010). In turn, the

Table 1

Number of wildlife-vehicle collisions in each month in 2009–2012 in the Lublin urban area

Month	Large mammals	Small mammals	Bats	Total
I	20	0	1	21
II	16	11	3	30
III	6	3	1	10
IV	13	9	4	26
V	32	31	9	72
VI	22	12	8	42
VII	6	13	13	32
VIII	9	11	20	40
IX	6	11	13	30
X	13	8	12	33
XI	14	5	4	23
XII	24	1	4	29
Total	181	115	92	388

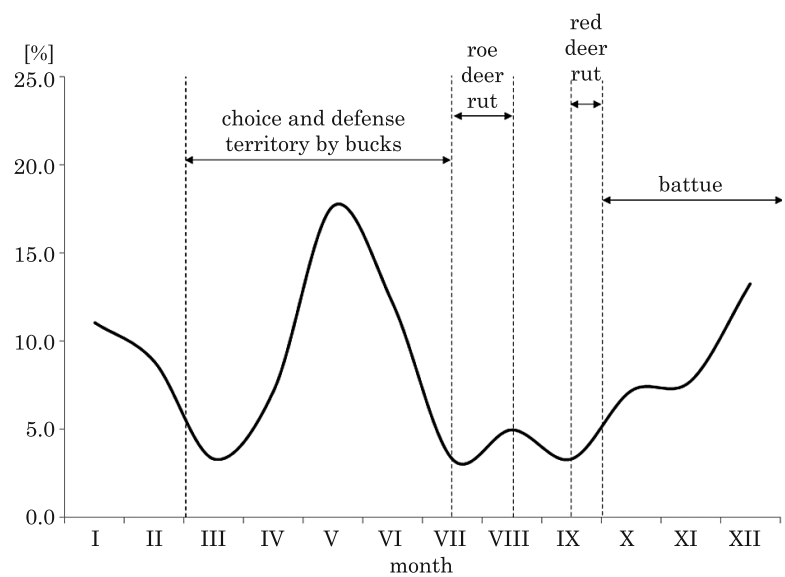

Fig. 1. Number of collisions with large mammals in each month in relation to their behaviour

increased number of wildlife-vehicle collisions in the winter period may be associated with the season for battues (between October 1 and January 15), in which wildlife animals are scared off and forced to flee, often cross transport routes. Additionally, during this period de-icing salt is applied onto roads as

a thawing agent, which may effectively attract animals close to transportation routes (BRUINDERINK at al. 1996).

The analysis of the number of vehicle collisions with small mammals (Table 1, Figure 2) in the respective months reveals that the number grows insignificantly during the vixen oestrus period (January – February). The lowest number of incidents is noted during the birth period (February/March). Next, a gradual increase in the number of collisions is observed in May, which may be associated with period of development of fox and marten offspring and increased activity of females questing for food for their young ones (GOSZCZYŃSKI 1995, GOSZCZYŃSKI at al. 1994, HERR 2008).

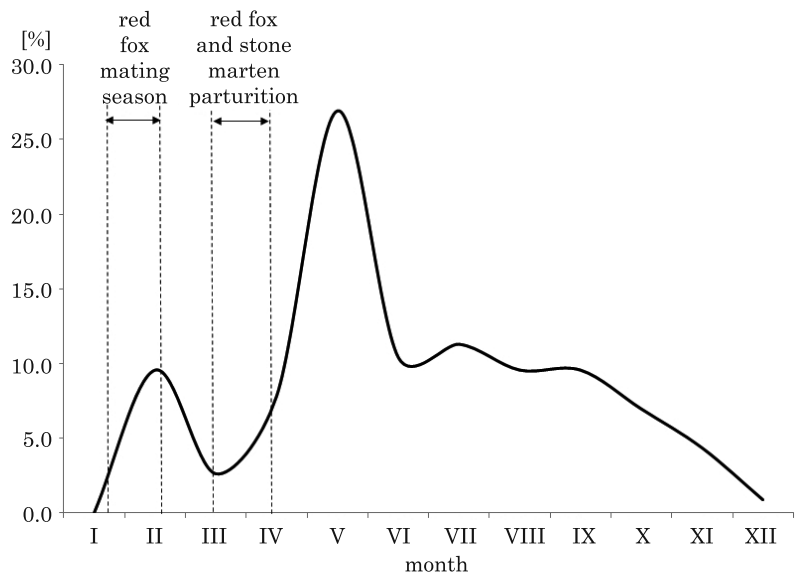

Fig. 2. Number of collisions with small mammals in each month in relation to their behaviour

In the case of bats, the increase in the number of wildlife-vehicle collisions in the summer period is evidently related to their behaviour (Table 1, Figure 3). The number of accidents involving bats is on the increase and is correlated with their greater post-hibernation activity. The peak of the number of incidents is noted in early autumn, i.e. at the beginning of the mating period (FUSZERA at al. 2010, RACEY 1982).

The analysed data on the localisation of the sites of wildlife-vehicle collisions indicate that exit roads were the most dangerous sites for animals, while roads in the city centre posed the lowest risk. The greatest number of wildlife-vehicle collisions was reported from Wincetgeo Witosa, Poligonowa, and Osmolicka Streets (Figure 4). Noteworthy, the land use along Wincentego

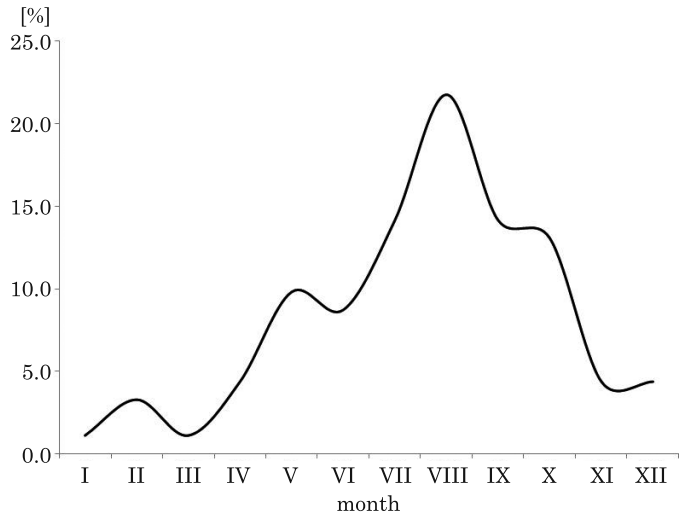

Fig. 3. Number of collisions with bats in each month in relation to their behaviour

Witosa Street has changed in recent years. Before 2012, the area was dominated by fields and fallows, while currently it has been turned into a commercial shopping centre area. Poligonowa Street is characterised by areas of uncultivated land and former allotments, which may serve as animal refuges. In turn, Osmolicka Street runs across Dąbrowa Forest, which is largely located in a protected landscape area with an artificial water reservoir, Lake Zemborzycki, on its right side. This promotes animal migration. Slightly fewer wildlife-vehicle collisions are noted in Spółdzielczości Pracy Alley, as it is a fenced road with acoustic screens and residential developments. These streets were also characterized by a relatively high intensity of movement especially in the mornings and evenings. These are the hours when the animals have greater mobility especially in autumn and winter when the day is short. The average intensity of traffic on Poligonowa Street is relatively low because it is in the range 300–500 (vehicles/hour), on Osmolicka over 1000 (vehicles/hour), and on Spółdzielczości Pracy and Wincentego Witosa Streets is very high because it varies from 1000 do1500 (vehicles / hour) and on some pieces on even higher than 1500 (Zarząd Dróg i Mostów w Lublinie).

Another cause of the increased number of accidents in the aforementioned streets can be related to the repair or reconstruction work carried out in these streets, which may have permanently altered the migration paths of wild animals. Approximately 50 km of roads in the Lublin urban area were reconstructed or built in 2010–2012. In this period, fragments of Zemborzycka Street (1150 m), Osmolicka Street (740 m), Spółdzielczości Pracy Alley

(878 m), and Smorawińskiego Street (1070 m extension of Spółdzielczości Pracy Alley) were reconstructed and Witosa Street (1150 m) was repaired (Zarząd Dróg i Mostów w Lublinie).

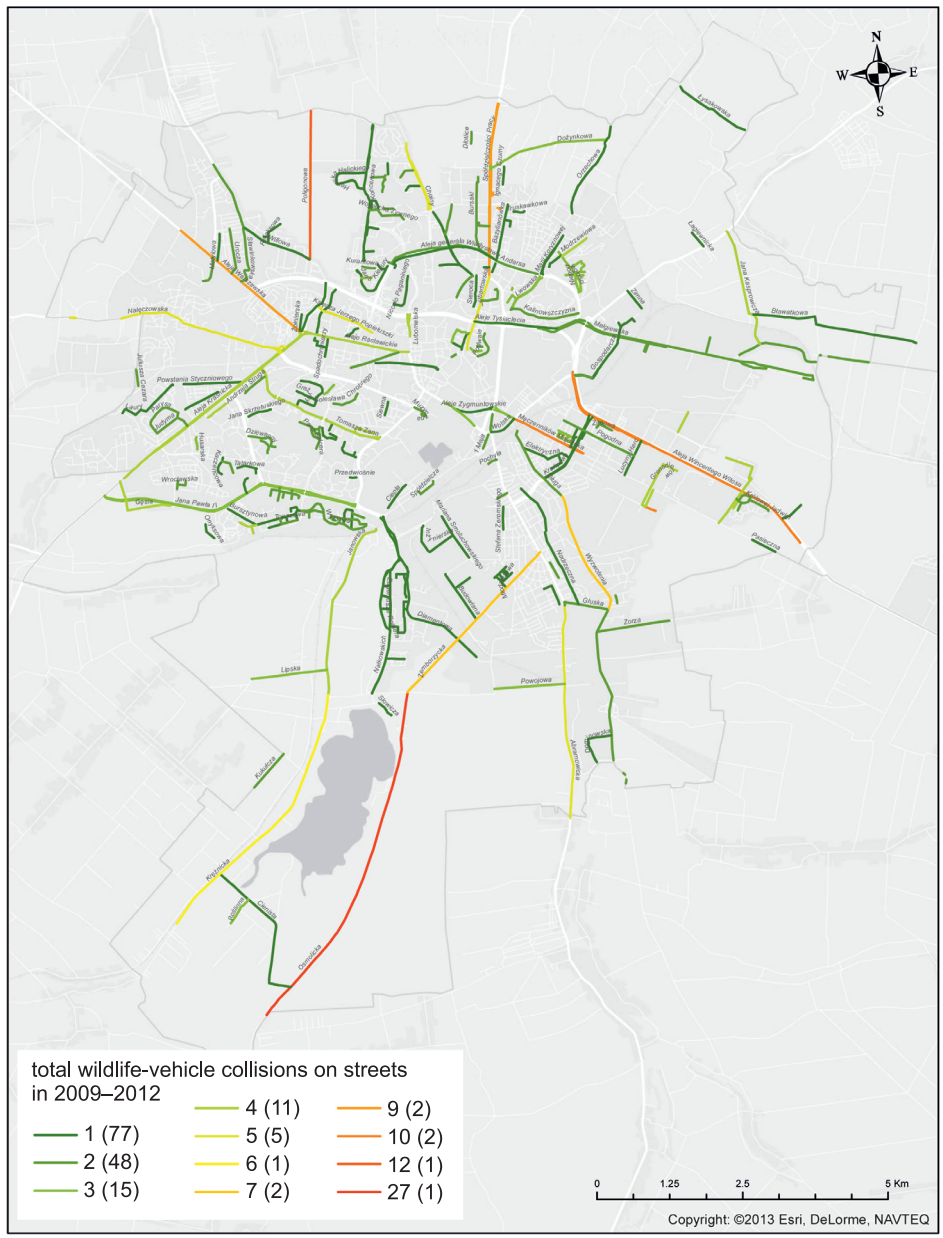

Fig. 4. Number of wildlife-vehicle collisions in the city of Lublin in 2009–2012

Conclusions

The reported results show the greatest number of wildlife-vehicle collisions on exit roads leading from the city centre (ORŁOWSKI and NOWAK 2006) – Figure 4. Presumably, this may be associated with the lack of speed limits and possible faults in the infrastructure arising already at the design stage.

There is a need for verification of the existing migration corridors in terms of their importance for the spatial and genetic permanence of populations and real long-term protection. The localisation of the corridors should be based on data of sites where animals cross public roads and spots of wildlife-vehicle collisions in urban areas, particularly in sites where the land along the roads will be transformed.

Animal populations have to adapt to the natural environment transformed by man. This is possible and effective in the case of some species (e.g. insects, rodents, predators), whereas other species such as large ungulates are not able to cope with the barriers created in the course of human development. From this point of view, the most important problem, i.e. degradation, loss, and fragmentation of habitats, it is not impossible to be solved, particularly in Poland, where the natural environment is relatively well preserved, in comparison with Western European countries. Therefore, the experience of other countries should be taken into account in the economic development in order to avoid the same mistakes and not to forget about the natural environment (INDYKIEWICZ at al. 2014, KLIMASZEWSKI 2011).

In Poland, there is only one universal warning sign with an image of a leaping deer "Caution, wild animals – A18b". The signs, however, are mounted routinely without consideration of local conditions, even if the probability of encountering a wild animal is relatively low. Due to its frequent presence, the sign is unnoticed by drivers. In 2008, for the first time in Poland, signs with images of a marten, roe deer, wild boar, hedgehog, or fox and the telephone number of a relevant service were displayed in the city of Łódź. In the first quarter of the year, a 20% decline in the number of wildlife-vehicle collisions was reported, compared with an analogous quarter of the previous year; additionally, aid provided to animals injured in an accident improved (BOROWSKA 2009). The success of the initiative proved the need for implementing such activity across the country. With knowledge of the routes and periods of migration of individual animal species, road administrators should be obligated to install warning signs at road crossings with migration corridors.

Wildlife-vehicle collisions (WVC) are a considerable problem in the transport route ecology due to their serious consequences for human life; they can result in economic losses and have a profound impact on many animal species (COFFIN 2007, CONOVER at al. 1995, FORMAN and ALEXANDER 1998, GROOT-

-BRUINDERINK and HAZEBROEK 1996). Therefore, prevention of the analysed incidents should be the major factor in designing and constructing roads and traffic management (ZUBEROGOITIA at al. 2014). This is usually accomplished through enforcement of national and international regulations for prevention of damage and for design of proactive actions in the most problematic sectors (IUELL at al. 2003). In this context, it is worth assessing the geographic distribution of WVC, determining the most problematic animal-human conflict areas, and strengthening preventive measures (FARELL and TAPPE 2007, GUNSON at al. 2010, MALO at al. 2004, ROSELL at al. 2013, ZUBEROGOITIA at al. 2014).

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EVALUATION OF YIELD, MORPHOLOGY AND QUALITY OF FRUITS OF CHERRY SILVERBERRY (*ELAEAGNUS MULTIFLORA* THUNB.) BIOTYPES UNDER CONDITIONS OF NORTH-EASTERN POLAND

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K e y w o r d s: cherry silverberry, yield, fruit biometry, chemical composition, fatty acids.

A b s t r a c t

The study evaluated three biotypes of cherry silverberry (obtained from the Institute for Fruit Growing in Samokhvalovitchy in Belarus) for cultivation under the conditions of north-eastern Poland in comparison to the form reproduced and cultivated at the University of Warmia and Mazury in Olsztyn. It was demonstrated that the natural conditions of Olsztyn permit cultivation of the examined cherry silverberry biotypes, although the yield was not high. The 01-1999 biotype from the Polish selection was characterized by a higher yield and weight of fruit, as well as by a higher fruit weight-to-stone weight ratio in comparison to biotypes selected in Belarus. The fruit of the examined biotypes also significantly differed in their chemical composition. Fruits of the 9-19-1996 biotype were characterized by high dry matter content, low acidity and a high sugar-to-acid ratio. The 9-24-1996 biotype fruits were characterized by the highest content of vitamin C. Both fruits and stones of cherry silverberry contained fat rich in n-3 and n-6 fatty acids. In cherry silverberry fruits, this ratio ranged from 1.2:1 to 1.4:1 in the pulp and from 1.4:1 to 1.8:1 in the stone.

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OCENA PLONOWANIA, MORFOLOGII I JAKOŚCI OWOCÓW BIOTYPÓW OLIWNIKA DŁUGOSZYPUŁKOWEGO (*ELAEAGNUS MULTIFLORA* THUNB.) W WARUNKACH PÓŁNOCNO-WSCHODNIEJ POLSKI

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S ł o w a k l u c z o w e: oliwnik długoszypułkowy, plon, biometria owoców, skład chemiczny, kwasy tłuszczowe.

A b s t r a k t

W pracy oceniono przydatność do uprawy w warunkach północno-wschodniej Polski 3 biotypów oliwnika długoszypułkowego otrzymanych z Instytutu Sadownictwa w Samochwałowiczach na Białorusi w porównaniu z formą rozmnożoną i uprawianą w UWM w Olsztynie. Wykazano, że warunki przyrodnicze Olsztyna umożliwiają uprawę badanych biotypów oliwnika wielokwiatowego, jednak plony nie należały do wysokich. Biotyp 01-1999 polskiej selekcji charakteryzował się wyższym plonowaniem oraz masą owoców, a także wyższym stosunkiem masy owocu do masy pestki niż biotypy wyselekcjonowane na Białorusi. Owoce badanych biotypów różniły się istotnie pod względem zawartości składników chemicznych. Owoce biotypu 9-19-1996 charakteryzowały się wysoką zawartością suchej masy, niską kwasowością i wysokim współczynnikiem kwasowocukrowym. Z kolei owoce biotypu 9-24-1996 charakteryzowały się najwyższą zawartością witaminy C. Zarówno owoce, jak i pestki oliwnika odznaczały się tłuszczem bogatym w kwasy tłuszczowe z grupy n-3 i n-6. W owocach oliwnika stosunek ten wynosił od 1,2:1 do 1,4:1 w miąższu oraz od 1,4:1 do 1,8:1 w pestce.

Introduction

Elaeagnus multiflora Thunb. – the cherry silverberry, also known as cherry elaeagnus or goumi, is a representative of the *Elaeagnus* L. genus – *Elaeagnaceae* Juss. family – which also includes the more popular common seabuckthorn – *Hippophaë rhamnoides* L. (SĘKOWSKI 1993, BUGAŁA 2000, SENETA and DOLATOWSKI 2012). The species is gaining increasing recognition as an ornamental plant and as a prospective fruit plant (BIENIEK et al. 2002).

The cherry silverberry is a native plant to China, Korea and Japan (KOŁBASINA 2003, BIENIEK et al. 2005). This is a shrub growing up to 3 m. Its shoots feature scarce thorns. The leaves are typical for *Elaeagnus* – the upper part of the leaf blade is green, while its bottom side is silvery (SENETA and DOLATOWSKI 2012). Since silverberry flowers give off a strong aroma resembling a smell of cinnamon and vanilla, this plant can be used for flavouring cakes

and other meals. They are well-pollinated by insects from the *Apidae* family. RADIUK and RADIUK (1997) report that the self-fertility rate can vary from 0% to 70%. The fruits are ellipsoidal, of a drupe-like type, up to 1 cm long and are set on stems. Their colour is red and they are juicy and sour, with a taste resembling that of red currant. Silverberries ripen at the end of June or at the beginning of July.

The cherry silverberry has low nutritional requirements and it grows best on dry, sandy and poor soils. However, it needs a lot of light to grow. The shrub can grow in one site for 25 years. Interest in the cultivation of this species has increased along with the development of house and allotment gardening. A symbiosis of this plant with ray fungi binding nitrogen from the air makes the silverberry a pioneer plant fertilizing the soil (HRYNIEWICKI 2008). The silverberry has a long vegetation period and it starts to lose leaves only after first ground frosts. Such a late leaf fall can causes shoot freezing in harsh winters. The shoots, even completely frozen, demonstrate good regeneration abilities and grow from the root neck in significant numbers (KAWECKI et al. 2007).

The first variety of the cherry silverberry, 'Sachaliński pierwyj'®, was cultivated in the Far Eastern Research Institute of Agriculture in Russia and registered and entered in 1999 into the State Register of Breeding Achievements Approved for Use. Other varieties were also cultivated later in Russia, such as 'Moneron'® and 'Taisa'® (2002), 'Kril'on'® (2006), 'Szikotan'® (2009), 'Juznyj'® (2009), 'Kunaszir'®(2011), 'Cunai' (2015) and 'Paramushir' (2016) (State Register of Breeding Achievements Approved for Use, 2016). The variety cultivated in Europe and in the USA is 'Sweet Scarlet'. Research in Poland started in 1995 at the Department of Horticulture in Olsztyn with three-year old cherry silverberries obtained from the Institute for Fruit Growing in Samokhvalovitchy in Belarus. The research focused on the ability of the cherry silverberry to germinate after the application of various stratification methods (KAWECKI et al. 2004). Currently, research is being conducted on more than ten seedlings in order to select the best forms that could be introduced into cultivation in Poland. This species is already being introduced into cultivation in Russia, Ukraine and the USA (BACZYŁO and SZAŁKIEWICZ 1996, SZAŁKIEWICZ and KAWECKI 2003). Its fruits, because of their rich chemical composition, reveal therapeutic and preventive values (BIENIEK et al. 2002, ISACZKIN et al. 2003). As results from the previous research concerning the chemical composition of the cherry silverberry fruit, they are rich in carotene, phenolic compounds, amino acids as well as macro and microelements (SZAŁKIEWICZ and KAWECKI 2003). The research conducted by LEE et al. (2010) demonstrated that the substances found in fruits of this species had antioxidant, anti-inflammatory and anti-proliferative effects and could be of

crucial importance in treating colon cancer. Fruits of this plant can be used in home processing to prepare juice, compote, jam or jelly and other food products. They demonstrate a toning effect and improve blood circulation, while fresh and processed fruit are recommended in abdominal pain. Leaves can be used as compresses for slow-healing wounds (KAWECKI et al. 2007).

The aim of the study was to evaluate usability for cultivation in conditions of north-eastern Poland of three biotypes of the cherry silverberry obtained from the Institute for Fruit Growing in Samokhvalovitchy in Belarus in comparison to the form reproduced and cultivated at the University of Warmia and Mazury in Olsztyn.

Materials and Methods

The experiment was established in 2007 in the Experimental Garden of the University of Warmia and Mazury in Olsztyn (north-eastern Poland, latitude: 53°50 N, 20°31 E). The climate of Olsztyn is typical for lakeland areas, determined by local elements of the environment, i.e. the land form and numerous lakes and forests. The research concerned 3 vegetatively propagated biotypes: 9-19-1996, 9-24-1996, 9-34-1996, obtained from the Institute for Fruit Growing in Samokhvalovitchy from the breeding farm E-2 (SZAŁKIEWICZ and KAWECKI 2003). The comparison of the biotypes also included evaluation of the 01-1999 biotype, obtained from seeds originating from a shrub cultivated in Olsztyn from 1999. The plants were planted in Albic Luvisolx (Arenic) soil, deeply flattened, produced from clays of pH in KCl 6.8 (*World reference...* 2014), in 4 x 2 m spacing. The shrubs started to fructify in the third year after planting. In 2012–2015, plant yield, morphological features and the chemical composition of the fruits were examined.

To describe the morphological features of fruits and stones, 100 fruits of each biotype were randomly selected. The research was conducted on fruits collected from plants in the consumption ripeness stage, when the fruits were fully red, it was usually the first week of July. For chemical analyzes, samples of about 0.4 kg of fresh fruit of each biotype were harvested. Immediately after harvesting, the seeds were extracted from fruits and fresh material, both fruit pulp and seeds, was analyzed for chemical composition.

Biochemical examinations of fruits included the following analyses:

– determination of the content of organic acid (*Przetwory owocowe...* PN-90/A-75101/04),

– determination of the content of sugars (*Przetwory owocowe...* PN-90 A-75101/07),

– determination of the content of dry matter (*Przetwory owocowe...* PN-90/A-75101/03),

– determination of the content of vitamin C (*Przetwory owocowe...* PN-90 A-75101/11),

– determination of fatty acids (*Analiza estrów metylowych...* PN-EN ISO 5508).

The results of chemical composition analysis were expressed as mg: 100 g^{-1} of fresh mass (vitamin C) or as % of fresh mass (organic acids, total saccharides, monosaccharides) and presented as an arithmetic mean of three parallel tests an statistically analysed with the use of a univariate analysis of variance. The significance of differences was calculated with Duncan's test at the significance level of 0.05 (for yield and morphological features of fruits) and of 0.01 (for chemical composition of fruits). Calculations were performed using Statistica 10.0 software. Percentage contents of fatty acids in the silverberry fruit pulp and stone are shown in the graphs on which the standard deviation was noted.

Results and Discussion

Mean yields of the examined cherry silverberry biotypes from the period of 2012–2015 ranged from 0.36 kg for the 9-34-1996 biotype to 1.32 kg for the 01-1999 biotype. These were relatively low yields and, as results from the statistical analysis, they were significantly varied (Table 1). The studies were conducted on plants after the fifth year of planting, since few fruits set in the fourth year. According to SZAŁKIEWICZ and KAWECKI (2003), most seedlings start yielding in fourth year after planting. In the research by those authors, the first trade yield in the berry plants experimental field of the Institute for Fruit Growing in Samokhvalovitchy in Belarus was higher and amounted from 1.5 to 4.5 kg from the shrub. KAPICZNIKOWA et al. (2005) reported that the yield obtained in Belarus and in Russia ranged from 3 to 10 kg and from 4 to 5 kg per shurb respectively. According to KOŁBASINA (2003), 5-year-old plants can yield

Table 1
Yield and morphology of fruits of the biotypes of cherry silverberry (means of 2012–2015) under the conditions of Olsztyn

Biotype	Yield [kg plant^{-1}]	The weight of 100 fruits [g]	Mean length of fruit [cm]	Mean width of fruit [cm]	Mean stalk length [cm]
01-1999	1.32^{d*}	112^{a}	1.28^{a}	0.96^{a}	3.77^{d}
9-34-1996	0.36^{a}	89^{a}	1.24^{a}	0.84^{a}	3.67^{c}
9-24-1996	0.71^{b}	105^{a}	1.26^{a}	0.99^{a}	3.40^{b}
9-19-1996	0.99^{c}	94^{a}	1.28^{a}	0.91^{a}	3.30^{a}

* The values denoted with the same letters are not significantly different at $p = 0.05$

3–4 kg fruit per shrub, 10-year-old plants – up to 15 kg and 20-year-old plants can yield up to 30 kg. SZAŁKIEWICZ and KAWECKI (2003) found that cultivation conditions, as well as climatic factors during the plant vegetation period, regardless of genetic factors, had a significant effect on yield and qualitative features of fruits. The cherry silverberry is a plant of low frost resistance and high regenerative properties (GORBUNOW and UDACZINA 1999). Since it is a photophilous plant, it must be provided with good light access (SĘKOWSKI 1993).

A statistical analysis of the morphological features of fruits and stones of the examined biotypes (Table 1 and Table 2) did not reveal any significant differences, except for the length of the fruit stalk, which significantly differentiated individual biotypes (Table 1). The longest stalks were observed in fruits of the 01-1999 biotype (3.77 cm), and the shortest one in the 9-19-196 biotype (3.30 cm).

Table 2

Morphological characteristics of stones from fruits of the biotypes of cherry silverberry (mean of 2012–2015)

Biotype	The weight of stone [g]	The length of stone [cm]	The width of stone [cm]	Fruit weight--to-stone weight ratio
01-1999	0.095^{a*}	1.08^{a}	0.35^{a}	11.79^{a}
9-34-1996	0.090^{a}	1.10^{a}	0.35^{a}	9.89^{a}
9-24-1996	0.105^{a}	1.10^{a}	0.38^{a}	10.00^{a}
9-19-1996	0.097^{a}	1.10^{a}	0.36^{a}	9.69^{a}

* For explanation see Table 1

The mean weight of 100 fruits of the examined biotypes was 100 g. The highest weight of 100 fruit, 112 g, was found for the 01-1999 biotype. In a study conducted by SZAŁKIEWICZ and KAWECKI (2003), the fruit weight of several cultivated forms under analysis obtained from the Institute for Fruit Growing in Samokhvalovitchy in Belarus ranged from 0.65 to 1.63 g, while according to KAWECKI et al. (2007), the weight of 100 fruits of the Russian cultivar 'Sachalinskij Pierwyj' was 140 g. What is of high importance in the evaluation of fruit quality, particularly in the context of their usability for processing, is the relation of the fruit weight to the stone weight. The current experiment did not demonstrate any significant differences between the biotypes as regards this parameter, which amounted from 9.69 for the 9-19-1996 biotype to 11.79 for the 01-99 biotype (Table 2).

Nevertheless, individual biotypes significantly differed in content of chemical components in fruits (Table 3).

Table 3

Biochemical composition of fruits of the cherry silverberry biotypes in fresh mass

Biotype	Dry matter [%]	Organic acids [%]	Total saccharides [%]	Monosa--ccharides [%]	Sugar/acid ratio	Vitamin C [mg 100 g^{-1}]
01-1999	12.64^{a*}	0.81^{a}	5.58^{b}	1.54^{a}	6.89^{b}	5.08^{b}
9-34-1996	13.44^{b}	1.20^{c}	6.30^{d}	1.92^{c}	5.25^{a}	4.22^{a}
9-24-1996	14.56^{c}	1.00^{b}	5.34^{a}	1.85^{b}	5.34^{a}	7.70^{c}
9-19-1996	15.55^{d}	0.78^{a}	5.77^{c}	1.96^{d}	7.40^{c}	4.96^{a}

* The values denoted with the same letters are not significantly different at $p = 0.01$

The dry matter content in fruit was quite varied and ranged from 12.64% in the 01-1999 biotype to 15.55% in the 9-19-1996 biotype. The biotypes of cherry silverberry evaluated by SZAŁKIEWICZ and KAWECKI (2003) contained 12.9–20.0% dry matter. Their maximum content was found in E 2 and E 3 forms, with the fruit weight amounting to 1 g. Similar results were obtained by WASIUK (2000).

Basic quality parameters of fruits determining their acceptance by consumers include the content of acids and sugars and their respective proportions. Those parameters also determine the level of evaluation of the sweet and sour taste of fruits. The value of the sugar/acid ratio was similar for fruits of the 9-34-1996 biotope and the 9-24-1996 biotope, which were one of the sourest. The fruits with a sugar/acid ratio higher than the values for the 01-1999 biotype were produced by the 9-19-1996 biotype, which was characterized by the lowest content of organic acids (Table 3). Fruits of this biotype, as well as of the 9-34-1996 biotype, contained the lowest amounts of vitamin C. The highest content of this vitamin, 7.7 mg 100 g^{-1}, was found for fruit of the 9-24-1996 biotype, while they were the least abundant in total sugar (5.34%). The highest amounts of this component, 6.30%, were found in fruits of the 9-34-1996 biotype. In the research by WASIUK (2000), the content of organic acid in fruits of several forms of the cherry silverberry cultivated in Ukraine ranged from 1.4% to 2.3%, while SZAŁKIEWICZ and KAWECKI (2003) obtained a higher content in fruits of other forms of this species cultivated in Belarus, i.e. between 2.14% and 2.52%. However, the highest differences were recorded as regards the content of ascorbic acid.

Slightly lower contents of ascorbic acid were found by SZAŁKIEWICZ and KAWECKI (2003): 2.35-4.34 mg 100 g^{-1} as compared to the present study, while the content of vitamin C in the fruits examined in Ukraine by WASIUK (2000) was significantly higher and amounted from 15.8 to 33.1 mg 100 g^{-1}. ISACZKIN et al. (2003) reported that the fruit contains 22 mg 100 g^{-1} vitamin C. The cherry silverberry also contains low amounts of fat. As reported by PIŁAT et al.

(2013), the total amount of lipids in cherry silverberry fruits amounted to about 1.4 g in 100 g of pulp. This fat contains from 48.7% to 54.5% unsaturated fatty acids, in which α-linolenic acid, known as omega-3 fatty acid, accounts for 17.5% to 20.8% and linolinic acid (omega-6) – from 21.8% to 25.9%.

The highest content of α-linolenic acid (20.8%) and linolinic acid (25.9%) in the pulp of the fruit was found for the 9-24-1996 biotype (Figure 1.). Lipids accumulated in stones of silverberry fruits contained an amount of oleic acid that was three times higher than the value found for lipids in the fruit pulp (Figure 2). The amount of oleic acid ranged from 19.3% (for the 9-24-1996 biotype) to 22.7% (for the 9-34-1996 biotype). According to dieticians,

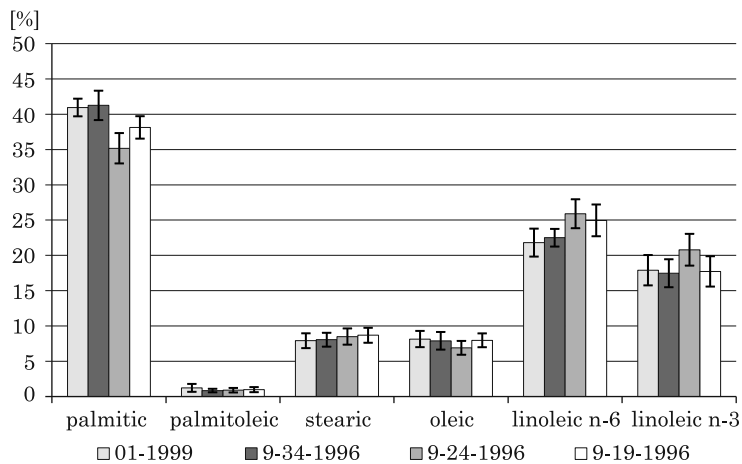

Fig 1. The fatty acids composition (% of total lipids) in the silverberry fruit pulp

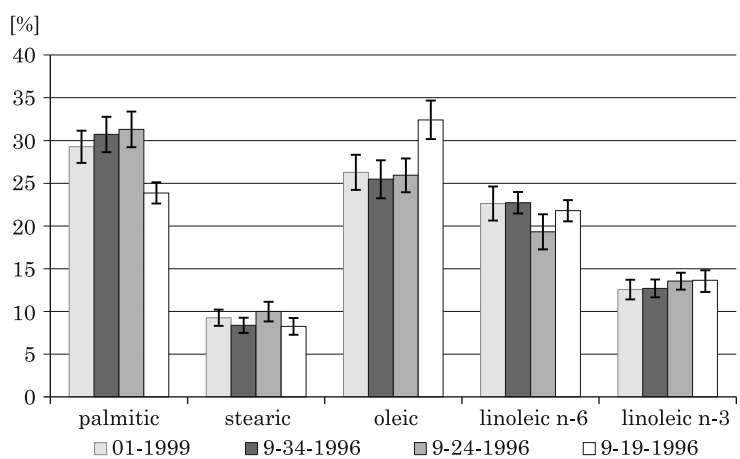

Fig 2. The fatty acids composition (% of total lipids) in the silverberry fruit stone

the omega-6 to omega-3 fatty acid ratio should range between 1:1 and 5:1, while in the silverberry fruit this ratio amounts to about 1.2:1 to 1.4:1 in the pulp, and from 1.4:1 to 1.8:1 in the stone of the silverberry fruits.

Conclusions

1. Although the natural conditions of Olsztyn make it possible to cultivate the examined biotypes of cherry silverberry, the yield was not high. The 01-1999 biotype of the Polish selection was characterized by a higher yield and weight of fruit, as well as by a higher relation of the fruit weight to the stone weight in comparison to biotypes selected in Belarus.

2. The fruits of the examined biotypes also significantly differed in terms of their chemical composition. Fruits of the 9-19-196 biotype were characterized by high dry matter content, low acidity and a high sugar/acid ratio. The 9-24-1996 biotype fruits were characterized by the highest content of vitamin C.

3. Both fruits and stones of cherry silverberry contained fat rich in n-3 and n-6 fatty acids. In cherry silverberry fruits, this ratio amounted from 1.2:1 to 1.4:1 in the pulp and from 1.4:1 to 1.8:1 in the stone.

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LICHENS OF SOKÓŁKA (PODLASIE, NORTH-EASTERN POLAND)

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K e y w o r d s: lichenized fungi, urban area, diversity, podlaskie voivodeship, Poland.

A b s t r a c t

The study presents the results of lichenological researches carried out in Sokółka town (Podlaskie voivodeship, north-eastern Poland). The investigations in the area of Sokółka were carried out in the years 2012–2013, on 50 research stands. In total, 76 species of lichens growing on natural and anthropogenic substrata have been recorded. The distributions of lichens in different urban lands are presented. Among them, protected species and lichens threatened in the country are distinguished.

POROSTY SOKÓŁKI (PODLASIE, POLSKA PÓŁNOCNO-WSCHODNIA)

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S ł o w a k l u c z o w e: grzyby zlichenizowane, obszar zurbanizowany, różnorodność, województwo podlaskie, Polska.

A b s t r a k t

W pracy przedstawiono wyniki lichenologicznych badań przeprowadzonych w Sokółce (województwo podlaskie, północno-wschodnia Polska) w latach 2012–2013 na 50 stanowiskach. Przedstawiono analizę występowania 76 gatunków porostów rosnących na podłożach naturalnych i antropogenicznych. Omówiono ich rozmieszczenie w różnych rejonach miasta. Odnotowano gatunki chronione i porosty zagrożone w kraju.

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Introduction

Towns and cities are an interesting objects of study of the lichen biota. Investigations of lichens in Poland have been carried out in a large number of big and small towns, frequently of a health-resort character, situated in the lowlands as well as the mountains (MATWIEJUK and KOROBKIEWICZ 2012a). On the territory of north-eastern Poland, lichen biota has been examined for cities, such as Olsztyn (KUBIAK 2005), Białystok (MATWIEJUK 2007), towns, such as Ciechanowiec (MATWIEJUK and KOLANKO 2007), Drohiczyn (MATWIEJUK 2009a), Ełk (MATWIEJUK and WÓJTOWICZ 2013), and villages, such as Mielnik (MATWIEJUK 2008), Boćki (MATWIEJUK 2009b), Białowieża (MATWIEJUK 2011), Narew (MATWIEJUK and KOROBKIEWICZ 2012b).

In this paper, the current knowledge about the lichens in urban land of Sokółka is presented. So far, only monitoring of lichens as bioindicators of air pollution has been conducted in Sokółka. On the basis of the occurrence of indicator epiphytic and epilithic lichen species, the scale of lichen sensitivity for the city has been developed and lichen zones have been designated (MATWIEJUK and KAŁUSKA 2014).

The aim of present study is the floristic documentation illustrating biodiversity of lichen biota including habitat conditions of species. In this paper also:

1. Determination of the species composition of lichens in town.
2. Distinction of species particularly associated to town.
3. Determination of the degree of diversity of lichen species in Sokółka located in different urban lands.
4. Characterization of the functional groups of lichens (morphological forms and habitat groups of lichens) typical of town areas.
5. Share of endangered and protected species in a man-transformed urban landscape are presented.

Study Area

Sokółka (53°24'N 23°30'E) is a town in north-eastern Poland. It is located in the area of Sokólskie Hills, in the northern part of Podlasie Lowland, by the Sokółka river (KONDRACKI 2002). The town is situated in the eastern part of Podlaskie voivodeship, on the edge of Knyszyn Primeval Forest, by the international road and railway route Warsaw–Bialystok–Grodno and running farther towards Minsk, Vilnius, Riga, St. Petersburg and Moscow. Sokółka is situated 16 km from the Polish-Belarusian border crossing in Kuźnica Białostocka. After crossing the border, Sokółka is the first city in the European Union.

The town has about 18.510 inhabitants and covers an area of 18.59 km.

The town rights were conferred by Zygmund III Waza King in 1609. Sokółka land is the region where many monuments of folk buildings and rural wooden architecture were preserved (POSTOŁOWICZ 2008).

Materials and Methods

Fieldwork research

Fieldwork research was conducted in the area of Sokółka in 2012–2013. In total, 50 research stands were determined. The research was based on a cartographic-point method (CIEŚLINSKI and TOBOLEWSKI 1989). The inventories of the lichen biota in many points in different urban land and habitat conditions were performed. This point was treated as a distinct stand, and its location was marked on the map with a scale of 1:20 000. The size of a single stand was different. It was dependent on a particular object, e.g. focusing of individual trees along roads, in built-up areas, in parks and cemeteries, etc. A location was considered as a stand within which the list of lichens was made from all available substrates. Collection of lichens was done from all possible substrates of their occurrence. The epiphytic lichens were examined for individual trees with a diameter of trunks > 30 cm. At each stand at least five trees were monitored. At each location all species of lichens on the bark of trees from the base up to 2.5 m were recorded.

These stands were established within the following land use differing in the degree of anthropogenic transformation:

1. Built–up areas:
   a) center – stands: 5–7, 9, 10, 12, 13, 15, 17, 30,
   b) periphery – stands: 2–4, 18, 20–22, 24, 25, 28, 29, 31–44, 47–50,
2. Green areas:
   a) parks – stands: 11, 14, 19,
   b) cemeteries – stands: 8, 23, 27,
   c) squares – stands: 1, 16,
   d) forest – stands: 26, 45, 46.

List of research stands in Sokółka

1. Railway station, square.
2. Kolejowa street.
3. 11-Listopada street.
4. Hugo Kołłątaj street.

5. Grodzieńska street.
6. Square near the church of Sts. Antoni Padewski.
7. Avenues of trees on the Roman Catholic cemetery.
8. Roman Catholic Cemetery.
9. Adam Mickiewicz street, park.
10. Władysław Sikorski street.
11. Józef Piłsudski street.
12. Walery Wróblewski street.
13. Piotr Sciegienny street.
14. Park at Kościuszki Square.
15. Plac Kościuszki street.
16. Square at the Orthodox Church.
17. 1 May street.
18. Kryńska street.
19. Park on a Green estate.
20. Area at the lagoon.
21. Osiedle Zielone street.
22. Jan Paweł II street.
23. Cemetery of Soviet Soldiers.
24. Marianska street.
25. Wincenty Witos street.
26. Forest at the city hospital.
27. Jewish cemetery.
28. Jan Henryk Dąbrowski street.
29. Władysław Sikorski street, section of the road from Towarowa street to Jan Henryk Dabrowski street.
30. Białostocka street.
31. Nowa street.
32. Dolna street.
33. Królowa Bona street.
34. Górna street.
35. Piaskowa street.
36. Żytnia street.
37. Wiosenna street.
38. Zacisze street.
39. Jan Tarasiewicz street.
40. Stanisław Mikołajczyk street.
41. Łąkowa street.
42. Adolf Sawicki street.
43. Bartosz Głowacki street, forest.
44. Grodzieńska street.
45. Lotnicy Lewoniewscy street, forest.

46. Osiedle Buchwałowo street, forest.
47. Stanisław Skarżyński street.
48. Agnieszka Osiecka street.
49. Stefan Batory street.
50. Franciszek Kleeberg street.

Taxonomic identification

For most taxa, taxonomic identification was carried out in laboratory conditions. Thin-layer chromatography (TLC) was used to identify the types of secondary metabolites, mainly from the genus *Lepraria*. This method was conducted in accordance with the guidelines from ORANGE et al. (2001). Lichen naming was adopted from FAŁTYNOWICZ and KOSSOWSKA (2016). The collected herbarium material is deposited in the Herbarium of the Institute of Biology, University of Bialystok. The taxa are listed alphabetically. For each taxon the following information is given: a substrate, the number of stands, a list of stands and threat category and protection status. The threat categories given for CIEŚLIŃSKI et al. (2006) and status of protection from Regulation (2014). In the list of species used the following abbreviations:

Ac – *Aesculus* x *carnea*, Ah – *Aesculus hippocastanum*, An – *Acer negundo*, Ap – *Acer platanoides*, As – *Acer saccharinum*, Bp – *Betula pendula*, Ca – *Caragana arborescens*, Cb – *Carpinus betulus*, Cj – *Cercidiphyllum japonicum*, Cr – *Crataegus* sp., Cv – *Cerasus vulgaris*, Fe – *Fraxinus excelsior*, Fo – *Forsythia* x *intermedia*, Hr – *Hippophaë rhamnoides*, Ld – *Larix decidua*, Lv – *Ligustrum vulgare*, Pa – *Populus alba*, Pc – *Pyrus communis*, Pd – *Prunus domestica*, Ph – *Philadelphus coronaries*, Pi – *Picea abies*, Pn – *Populus nigra*, Pp – *Picea pungens*, Ps – *Pinus sylvestris*, Pt – *Populus tremula*, Sa – *Salix alba*, Si – *Sorbus intermedia*, So – *Sorbus aucuparia*, Qr – *Quercus robur*, Qu – *Quercus rubra*, Sy – *Symphoricarpos albus*, Tc – *Tilia cordata*, Th – *Thuja occidentalis*, Tp – *Tilia plathyphyllos*, Ul – *Ulmus laevis*, EN – endangered, VU – vulnerable, NT – near threatened; §§ – strict protection, § – partial protection.

Characteristic of species

In order to characterize recorded taxa the following data were included:

1. Morphological forms of thallus by NIMIS and MARTELLOS (2008).
2. Habitat groups.
3. Degree of prevalence – based on the frequency of occurrence in the study area (Table 1).

Table 1

The categories for specific characteristics of lichens

Characteristic	Categories
Morphological forms	C – crustose S – squamulose Fw – wide foliose type *Parmelia* Fn – narrow foliose type *Physcia* F – fruticose
Habitat group	epiphytic = Corticolous: growing on the bark of trees and shrubs epigeic = Terricolous: growing on soil epixylic = Lignicolous: growing on rotten, decayed and dead wood epilithic = Saxicolous: growing on rocks and concrete
Degree of prevalence	very rare – taxon occurring for 1–2 stands rare – taxon occurring for 3–5 stands frequent – taxon occurring for 6–15 stands common – taxon occurring for > 15 stands

Statistical analysis

The differences between the number of species in the stands located in the different types of urban land were verified by using the Kruskal-Wallis test.

Results

Ecological Grups

In total, 76 lichen species were recorded in Sokółka. The lichens are represented by 42 genera. The most abundant numbers of species are genera: *Lecanora* (10), *Physcia* (5), and *Ramalina* (4).

Lichens occurs on all substrata likely to be colonized – on the bark of deciduous and coniferous trees and shrubs, wooden constructions, soil, stones and concrete.

Epiphytes

The biota is dominated by epiphytes – 53 species, including 32 found only on the bark of trees. The richest lichen biota has been recorded on the bark of deciduous trees – *Acer platanoides* (39 species), *Tilia cordata* (37), *Fraxinus excelsior* (27) and *Betula penudla* (21). The epiphytic biota of the maple is of greater diversity. Rare taxa have been identified on its bark, such as, *Anaptychia ciliaris*, *Bryoria fuscescens, Melanelixia subargentifera, Pleurosticta*

acetabulum, Ramalina fastigiata and *R. pollinaria*. Most of the observed species are found in more sunlight and little shading. On bark of most roadside trees, high participation in lichen biota is exhibited by nitrophilous macrolichens of genera *Physcia*, *Physconia*, *Ramalina* and *Xanthoria*.

Epilythes

The second largest habitat group – 33 species, comprises epilithic lichens, of which 22 are exclusive epilythes. These lichens grows on both natural and anthropogenic substrates. Stones can be found in urban landscape, in the open area, as well as within built-up areas (walls, underpinnings and gravestones). Rich lichen biota occurs also on artificial substrata with properties resembling those of rocks, such as concrete, mortar and bricks. Anthropogenic substrates were colonized by calciphilous species and also by species tolerant towards the presence of calcium carbonate. They are accompanied by numerous nitrophilous species of family *Physciaceae.* A distinctive tendency of the discussed group of lichens to occupy places in direct sunlight has been shown.

Epixylithes

Epixylic lichens are represented only by 15 species. On the territory of Sokółka, epixylic lichens grows on mainly wooden constructions (fences, poles, crosses and farm outbuildings). Epixylic lichens are a little specific ecological group. Only one taxa was recorded exclusively on wood, the others were growing also on other substrates. The exclusive species is *Platismatia glauca.* Most of the observed epixylic lichens are common lichenized fungi.

Epigeits

Terricolous lichens were represented by as little as one hemerophilous species of the genus *Peltigera*: *P. rufescens*.

Morphological forms

Lichens are represented by all morphological forms. In the biota of the investigated area, the most dominant lichens are the ones which form different types of crustose thalli. They make up 43% of the overall number of the species.

The second largest group consists of foliose lichens (36%). Lichens of fruticose thallus are the less numerous group comprising 11% of the overall number of biota. The participation of lichens from other morphological groups is insignificant and amounts to around 1%.

Local frequency

In lichen biota of Sokółka, very rare (28.6% of the biota) and rare species (28.6%) are dominate. These are: *Candelariella coralliza, Lecanora rupicola, Melanelia subargentifera, Pertusaria coccodes, Ramalina fastigiata, Usnea hirta* and others. The frequent lichens are represented by 18 species (23.4%). Fifteen taxa (19.4%) were recorded in more than 15 stands (common species). Common species characterised by a broad ecological scale. The following species were recorded most frequently: *Phaeophyscia orbicularis* (46 stands), *Xanthoria parietina* (44), *Protoparmeliopsis muralis* (36), *Myriolecis dispersa* (34), *Physcia dubia* (33), *Candelariella xanthostigma* (32).

Participation of vulnerable and protected lichens

The recorded biota includes 12 species threatened with extinction in Poland (15.8%), including four endangered species (EN): *Anaptychia ciliaris, Pleurosticta acetabulum, Ramalina fastigiata* and *R. fraxinea*, five vulnerable species (VU): *Bryoria fuscescens, Parmelina tiliacea, Ramalina farinacea, R. pollinaria* and *Usnea hirta,* and three near threatened species (NT): *Evernia prunastri, Hypogymnia tubulosa* and *Pertusaria coccodes*. Eleven (14.5%) of the species given are protected in Poland, including six partially protected (*Bryoria fuscescenes, Hypogymnia tubulosa, Pleurosticta acetabulum, Ramalina farinacea, R. pollinaria, Usnea hirta*) and five strictly protected (*Anaptychia ciliaris, Parmelina tiliacea, Ramalina fastigiata, R. fraxinea, Xanthoparmelia verruculifera*).

List of taxa

The list presented below includes 77 lichen taxa species found in the study area.

Acarospora fuscata (Nyl.) Arnold – stone, gravestones, concrete structures; rare species; number of stands: 5, stands: 3, 6, 8, 27, 50.

Amandinea punctata (Hoffm.) Coppins & Scheid. – Tc, Ap; rare species, number of stands: 4, stands: 3, 6, 7, 47.

Anaptychia ciliaris (Schleich.) Vězda. – Ap, Fe; rare species, number of stands: 5, stands: 1, 5, 18, 19, EN, §§.

Athalia holocarpa (Hoffm.) Arup, Froden Szchting – concrete structures, gravestones, terrzazzo tombstones, metal; rare species, number of stands: 4, stands: 8, 18, 25, 27

Bryoria fuscescens (Gyeln.) Brodo & D. Hawksw. – Ap, Qr, Qu; rare species, number of stands: 4, stands: 7, 12, 21, 49, VU, §.

Calogaya decipiens (Hoffm.) Arup, Froden & Szchting – stone, stone structures, concrete structures; common species, number of stands: 26, stands: 1, 3, 4, 6, 8, 10, 11, 13, 16–18, 20–22, 24, 28, 29, 32, 33, 36, 37, 40, 43, 48–50.

Calogaya pusilla (A. Massal.) Arup, Frödén & Szchting – Ap, Ah, stone, concrete structures, terrzazzo tombstones, stone structures; common species, number of stands: 18, stands: 1–3, 6, 8, 10, 13, 16–18, 21, 22, 29, 35, 36, 40, 47, 50

Candelaria concolor (Dicks.) Stein – Ap, Ah, Fe, Tc; frequent species, number of stands: 8, stands: 1, 3, 6, 7, 12, 14, 17,18

Candelariella aurella (Hoffm.) Zahlbr. – Tc, stone, concrete structures, stone structures, metal, frequent species number of stands: 15, stands: 3, 6, 8, 10, 14, 16, 20–23, 25, 27, 31, 35, 47,

Candelariella coralliza (Nyl.) H. Magn. – matzevas; very rare species, number of stands: 1, stand: 27

Candelariella vitellina (Hoffm.) Müll. Arg. – wood, concrete structures, stone, gravestones; rare species, number of stands: 4, stands: 6, 8, 27, 49.

Candelariella xanthostigma (Ach.) Lettau – Ap, Ah, Bp, Cb, Cj, Cr, Fe, Ld, Pa, Pn, Pd, Pc, Qr, Qu, Sa, Th, Tc, Tp, Ul; common species, number of stands: 32, stands: 1, 3, 6–19, 21, 23, 24, 27, 29, 30, 34, 36, 38, 39, 41–42, 44, 46, 47, 50.

Catillaria nigroclavata (Nyl.) Schuler – Ah; very rare species, number of stands: 1, stand: 7.

Circinaria calcarea (L.) A. Nordin, Savic & Tibell – concrete structures; rare species, number of stands: 3, stands: 8, 14, 22.

Cladonia coniocraea auct. – Bp, Tc, wood; rare species, number of stands: 3, stands: 6, 8, 23.

Cladonia fimbriata (L.) Fr. – Bp, Tc; rare species, number of stands: 3, stands: 6, 7, 23.

Cladonia glauca Flörke – Pt; very rare species, number of stands: 1, stand: 44.

Evernia prunastri (L.) Ach. – Ap, As, Bp, Fe, Ld, Pn, Qr, Tc, Ul; frequent species, number of stands: 11, stands: 7–10, 12, 14, 18–20, 23, 50, NT.

Flavoplaca citrina (Hoffm.) Arup, Froden & Szchting – stone, concrete structures, terrzazzo tombstones, metal; frequent species, number of stands: 14, stands: 3, 4, 6, 8, 10, 28, 29, 31–33, 37, 42, 43, 47.

Hypocenomyce scalaris (Ach.) Choisy – Bp, Ld, Ps, Tc, wood; frequent species, number of stands: 11, stands: 3, 6–10, 23, 27, 34, 45, 46

Hypogymnia physodes (L.) Nyl. – Ap, As, Bp, Cr, Ld, Pi, Ps, Qr, Tc, wood, stumps; frequent species, number of stands: 15, stands: 7–11, 13, 17, 18, 20, 21, 23, 26, 27, 36, 49.

Hypogymnia tubulosa (Schaer.) Hav. – Ap, Bp, Tc; rare species, number of stands: 3, stands: 7, 9, 19, NT, §.

Lecania erysibe (Ach.) Mudd – concrete structures; very rare species, number of stands: 2, stands: 8, 11.

Lecanora allophana (Ach.) Nyl. – Ap, Ah, Bp, Fe, Tc; frequent species, number of stands: 8, stands: 6–9, 13, 14, 19, 27.

Lecanora carpinea (L.) Vain. – Ap, Fe, Tc; frequent species, number of stands: 10, stands: 6, 8, 9, 13, 14, 20, 27, 29, 30, 50.

Lecanora chlarotera Nyl. – An, Ap; very rare species, number of stands: 2, stands: 7, 17.

Lecanora conizaeoides Nyl. – Ps, Qr; very rare species, number of stands: 2, stands: 12, 26.

Lecanora expallens Ach. – Ap, Fe, Pn; very rare species, number of stands: 2, stands: 19, 23.

Lecanora polytropa (Ehrh. ex Hoffm.) Rabenh. – matzevas; number of stands: 1, very rare species, stand: 27.

Lecanora pulicaris (Pers.) Ach. – Fe, So, Tc; frequent species, number of stands: 6, stands: 8, 16, 19–21, 25.

Lecanora rupicola (L.) Zahlbr. – matzevas; very rare species, number of stands: 1, stand: 27.

Lecanora symmicta (Ach.) Ach. – Tc, very rare species, number of stands: 1, stand: 24.

Lecanora varia (Hoffm.) Ach. – Bp, Tc, wood, rare species, number of stands: 3, stands: 8, 23, 24.

Lecidella elaeochroma (Ach.) Choisy – Ap, Ah, Fe, Tc, Tp; frequent species, number of stands: 6, stands: 6–9, 14, 19.

Lecidella stigmatea (Ach.) Hertel & Leuckert – concrete structures; frequent species, number of stands: 6, stands: 2, 6, 8, 10, 23, 25.

Lepraria incana (L.) Ach. – Ap, Bp, Cb, Fe, Ld, Tc; rare species, number of stands: 5, stands: 6–9, 23.

Melanelixia fuliginosa (Fr. ex Duby) O. Blanco & al. – Ap, Cj, Fe, Tc, Tp, stone; common species, number of stands: 16, stands: 1, 6–10, 12, 16, 18–21, 27, 31, 49, 50.

Melanelixia subargentifera (Nyl.) O. Blanco & al. – Tc; very rare species, number of stands: 1, stand: 8, VU.

Melanoxalea exasperatula (Duby) O. Blanco & al. – Ah, Cb, Fe, Tc, root painted, metal; frequent species, number of stands: 6, stands: 8, 7, 11, 19, 20, 23.

Myriolecis albescens (Hoffm.) Śliwa, Zhao Xin & Lumbsch – Ap, Cj, Sa, concrete structures, gravestones, stone structures; common species, number of stands: 19, stands: 2–4, 6, 8, 10, 11, 13, 16–18, 20–22, 28, 29, 48–50.

Myriolecis crenulata (Hook.) Śliwa, Zhao Xin & Lumbsch – terrzazzo tombstones; very rare species, number of stands: 1, stand: 8.

Myriolecis dispersa (Pers.) Śliwa, Zhao Xin & Lumbsch – concrete structures, stone, stone construction, gravestones; common species, number of stands: 34, stands: 1–4, 6, 8, 10, 11, 13, 16–18, 20–24, 28, 29–41, 43, 48–50.

Myriolecis hagenii (Ach.) Śliwa, Zhao Xin & Lumbsch – Ap; very rare species, number of stands: 1, stand: 18.

Parmelia sulcata Taylor – Ap, As, Ah, Bp, Cj, Fe, Ld, Pv, Pi, Pd, Qr, Sa, So, Tc, Ul, wood, matzevas, concrete structures, metal; common species, number of stands: 24, stands: 1, 6–12, 14–23, 25, 27, 29–31, 50.

Parmelina tiliacea (Hoffm.) Hale – Ap, Ah, Cb, Fe, Tc, Ul; rare species, number of stands: 4, stands: 6–8, 10, VU, §§.

Peltigera rufescens (Weiss) Humb. – soil; very rare species, number of stands: 2, stands: 23, 46.

Pertusaria coccodes (Ach.) Nyl. – Ap, Tc; very rare species, number of stands: 2, stands: 19, 21, NT.

Phaeophyscia nigricans (Florke) Moberg – concrete; frequent species, number of stands: 6, stands: 1, 20, 23, 37, 39, 43.

Phaeophyscia orbicularis (Neck.) Moberg – An, Ap, Ac, Ah, Bp, Ca, Cb, Cv, Cj, Cr, Fo, Fe, Ld, Lv, Ph, Pp, Pa, Pn, Pd, Qr, Qu, Sa, So, Sy, Th, Tc, Tp, Ul, stone, wood, root painted, concrete structures, terrzazzo tombstones, stone, stone construction, metal; common species, number of stands: 46, stands: 1–25, 27–31, 33–36, 38–47, 49, 50.

Phlyctis argena (Ach.) Flot. – An, Ap, Cb, Fe, Pv, Pa, Pc, Tc, Ul; common species, number of stands: 20, stands: 3, 5–8, 12, 18, 19, 21, 23, 27, 36, 38–42, 44, 46, 50.

Physcia adscendens (Fr.) H. Olivier – Ap, Bp, Fe, Sa, So, Tc, Tp, Ul, wood, concrete structures, stone, metal; common species, number of stands: 28, stands: 1, 2, 6–14, 16–21, 23, 25, 27–29, 31, 33, 35, 39, 42, 48.

Physcia caesia (Hoffm.) Fürnrohr – concrete structures, concrete wall, stone, matzevas; frequent species, number of stands: 11, stands: 1, 3, 14, 23, 27, 31, 35, 37–39, 43.

Physcia dubia (Hoffm.) Lettau – Ap, As, Ah, Bp, Cb, Cv, Cr, Fe, Hr, Ld, Pn, Pd, Pc, Qr, So, Tc, Ul, wood, concrete structures, metal; frequent species, number of stands: 33, stands: 1–3, 6–17, 19–25, 31, 34, 35, 41, 43, 45–50.

Physcia dubia var. *teretiuscula* (Ach.) Clauzade & Cl. Roux – matzevas; very rare species, number of stands: 1, stand: 27.

Physcia stellaris (L.) Nyl. subsp. *stellaris* – An, Ap, Bp, Fe, Ps, Pn, Pd, So, Si, Tc, wood, stumps; frequent species, number of stands: 15, stands: 1, 2, 10, 11, 20, 22, 23, 25, 27, 36, 41, 43, 45, 46, 48.

Physcia tenella (Scop.) DC. – Ap, Bp, Fe, Pd, Ul, metal; frequent species, number of stands: 10, stands: 1, 6, 7, 16, 18, 19, 22, 27, 35, 38.

Physconia enteroxantha (Nyl.) Poelt – Ap, Bp, Cj, Fe, Pn, Pc, Sa, So, Tc, Ul; common species, number of stands: 26, stands: 1–3, 6, 7, 9, 11, 15, 16, 19–21, 23, 27, 31, 46, 47, 48.

Physconia grisea (Lam.) Poelt – Ap, Ah, Bp, Fe, Sa, Tc; frequent species, number of stands: 14, stands: 6–10, 12, 14, 18–21, 23, 24, 50.

Platismatia glauca (L.) W.L. Culb. & C.F. Culb. – wooden crosses; very rare species, number of stands: 1, stand: 8.

Pleurosticta acetabulum (Neck.) Elix & Lumbsch – Ap, Fe, Tc; rare species, number of stands: 4, stands: 6, 7, 18, 19, EN, §.

Polycauliona candelaria (L.) Frödén, Arup & Szchting – Ap, Fe; rare species, number of stands: 4, stands: 2, 14, 42, 48.

Polycauliona polycarpa (Hoffm.) Frödén, Arup & Szchting – Ap, Ah, Bp, Hr, Ld, Pi, Pp, Si, Tc, wood, stumps, metal; common species, number of stands: 29, stands: 1, 3, 7, 9, 10, 11, 14, 16, 17, 19–21, 23, 25, 34–36, 41, 43, 45, 46.

Porpidia crustulata (Ach.) Hertel & Knoph – concrete structures; rare species, number of stands: 3, stands: 1, 36, 40.

Protoparmeliopsis muralis (Schreb.) Choisy – stone, concrete structures, concrete wall, stone structures, matzevas, metal; common species, number of stands: 36, stands: 1, 3, 6, 8, 10, 11, 14, 16, 22, 27–29, 31–38, 40–44, 47, 49, 50.

Ramalina farinacea (L.) Ach. – Ap, Tc; rare species, number of stands: 3, stands: 8, 18, 19, VU, §.

Ramalina fastigiata (Pers.) Ach. – Ap; very rare species, number of stands: 1, stand: 18, EN, §§.

Ramalina fraxinea (L.) Ach. – Ap, Fe, Tc; frequent species, number of stands: 15, stands: 7, 8, 13, 18, 19, 21, 23, 27, 36, 38, 39, 40, 42, 44, 46, EN, §§.

Ramalina pollinaria (Westr.) Ach. – Ap, Fe, Pn; rare species, number of stands: 4, stands: 8, 18, 19, 23, VU, §.

Rusavskia elegans (Link) S.Y. Kondr. & Kärnefelt – concrete structures, stone; rare species, number of stands: 3, stands: 16, 18, 29.

Scoliciosporum chlorococcum (Graeve ex Stenh.) Vězda – Bp, wood; rare species, number of stands: 3, stands: 43, 45, 46.

Usnea hirta (L.) Weber ex F.H. Wigg. – Ps; very rare species, number of stands: 2, stands: 8, 27, VU, §.

Verrucaria muralis Ach. – concrete structures, concrete wall; rare species, number of stands: 5, stands: 6, 11, 20, 28, 29.

Verrucaria nigrescens Pers. – concrete structures; rare species, number of stands: 3, stands: 23, 32, 44.

Xanthoparmelia conspersa (Ach.) Hale – matzevas; very rare species, number of stands: 1, stand: 27.

Xanthoparmelia loxodes (Nyl.) O. Blanco & al. – matzevas; number of stands: 1, very rare species, stand: 27.

Xanthoparmelia verruculifera (Nyl.) O. Blanco & al. – matzevas; number of stands: 1, very rare species, stand: 27, §§.

Xanthoria parietina (L.) Th. Fr. – An, Ap, As, Ac, Ah, Bp, Cb, Cv, Cj, Cr, Fo, Fe, Lv, Pv, Ph, Pa, Pn, Pt, Pd, Qr, Qu, Sa, So, Si, Sy, Th, Tc, Tp, Ul, wood, stone, root painted, concrete structures, metal; common species, number of stands: 44, stands: 1–8, 10–25, 27–31, 35, 36, 38–50.

The influence of different urban land on lichen biota

The values of the degree of species diversity for all species and for different morphological forms taking into account different urban land are presented in Table 2.

Table 2

The degree of variation in species and relative species richness of selected parameters X ± *SD*

Parameters	*1*	*2*	*3*	*4*	*5*	*6*
Nalls	15.20 ± 9.41	11.21 ± 5.39	30.67 ± 8.33	19.67 ± 5.51	20.00 ± 1.41	8.00 ± 4.58
NsC	4.90 ± 4.95	3.40 ± 1.68	8.00 ± 6.66	4.67 ± 5.51	4.00 ± 1.41	1.00 ± 1.00
NsS	0.70 ± 0.67	0.17 ± 0.47	1.00 ± 0.00	0.33 ± 1.53	0.50 ± 0.71	0.67 ± 0.58
NsFn	4.90 ± 2.51	5.31 ± 2.09	8.00 ± 1.73	8.67 ± 0.58	12.00 ± 1.41	3.67 ± 3.51
NsFw	3.50 ± 2.06	1.55 ± 1.35	6.33 ± 1.53	3.67 ± 2.08	3.00 ± 0.00	1.33 ± 0.58
NsF	1.20 ± 1.23	0.76 ± 1.57	4.00 ± 2.64	2.33 ± 3.21	0.50 ± 0.71	0.67 ± 0.58

Explanations: *1* – center, *2* – periphery, *3* – cemeteries, *4* – parks, *5* – squares, *6* – forest;
Nalls – the number of all species; NsC – the number of crustose species, NsS – the number of squamulose species, NsFn – the number of narrow foliose species, NsFw – the number of wide foliose species, NsF – the number of fruticose species.

Diversity of species

The degree of species diversity of lichens has developed at a higher level in green areas (cemeteries, squares, parks) compared with the built-up areas (Figure 1). In green areas, a greater percentage of species was noted within cemeteries, squares and at parks, while a smaller number of taxa was observed in forest located within the city boundaries. The total number of identified species differ significantly between the different types of land use.

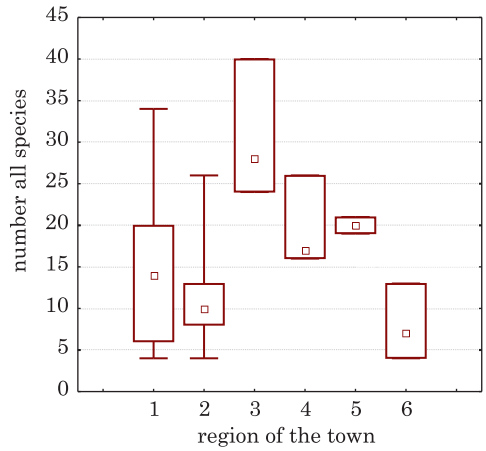

Fig. 1. The range of variation of the total number of lichen species found in Sokółka, depending on their belonging of the land use of the town (1 – center, 2 – periphery, 3 – cemeteries, 4 – parks, 5 – squares, 6 – forest)

Morphological form of thallus

There was effect of the covariate on the percentage of species of particular types of thallus. The share of crustose lichens is higher in regions located in green area (cemeteries, parks) and in centrum of city (Figure 2). For the most part, significantly lower values of the examined parameter were observed in forest. In relation to the number of species of squamulose lichens the difference was reported only on surfaces of green area located in parks. The average number of species of narrow foliose lichens differed significantly between the surfaces of the stands located on build area and green areas. A higher share of narrow foliose lichens was noted in selected stands in the squares, parks and cemeteries. The share of lichens of wide foliose thalli of type *Parmelia* is higher in localities associated with green area (cemeteries, parks). The highest average number of fruticose lichen species was recorded in city in cemeteries and parks (Figure 2).

Discussion

The diversity of lichen species in Sokółka town is not very high. The lichen biota of Sokółka consists of 76 species of lichens. This number is relatively small considering the results of research conducted in a similar tows in north-eastern part of country, e.g. in Ciechanowiec (MATWIEJUK and KOLANKO 2007) 114 species of lichens were observed, in Boćki (MATWIEJUK 2009b) – 118,

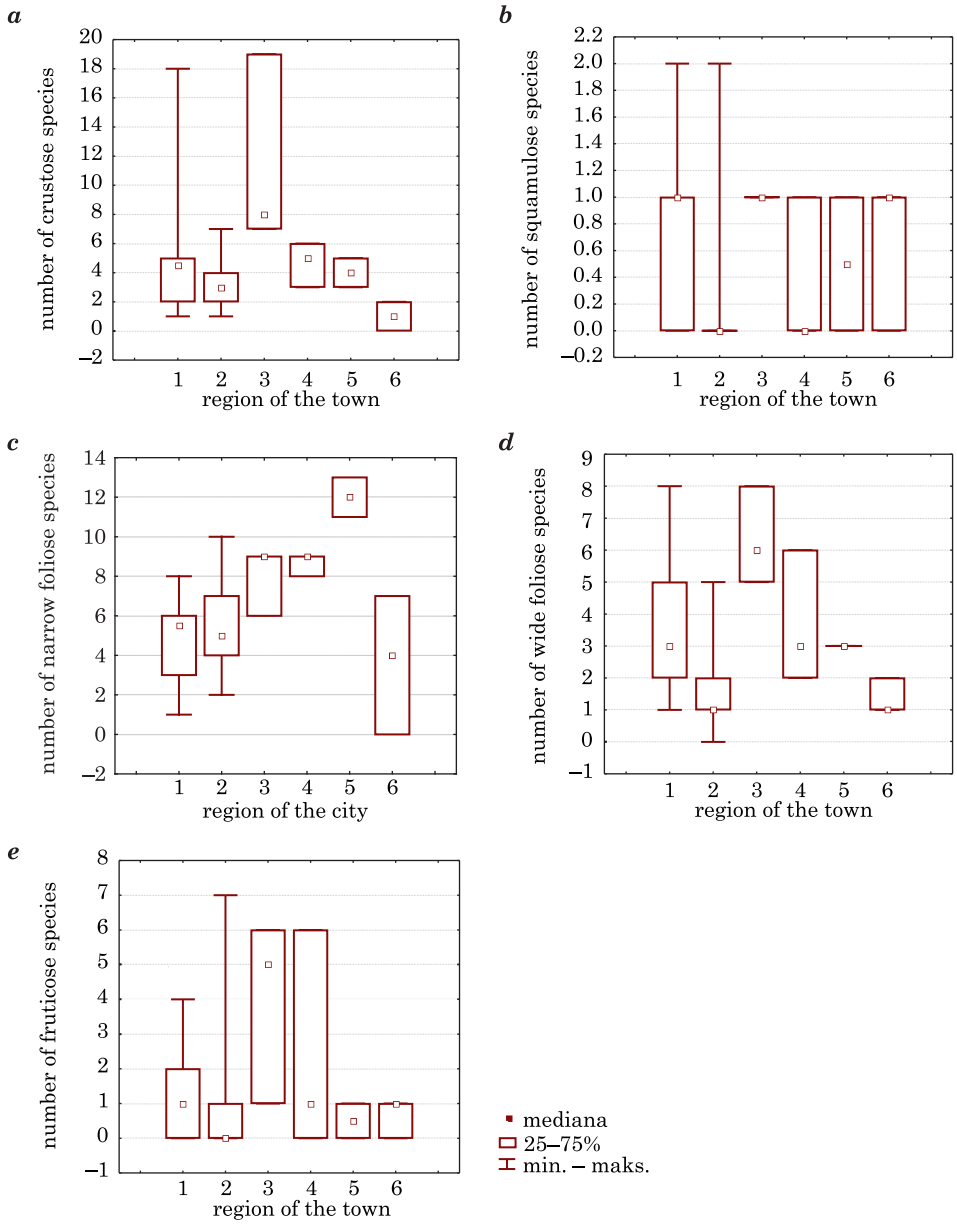

Fig. 2. The range of variation of the number of lichen species of crustose (a), squamulose (b), narrow foliose (c), wide foliose (d), fruticose thalli (e) found in Sokółka, depending on their belonging of the land use of the town (1 – center, 2 – periphery, 3 – cemeteries, 4 – parks, 5 – squares, 6 – forest)

in Białowieża (MATWIEJUK 2011) – 109, in Mielnik (MATWIEJUK 2008) – 91, in Narew (MATWIEJUK and KOROBKIEWICZ 2012b) – 95, in Drohiczyn (MATWIEJUK 2009a) – 86, in Ełk (MATWIEJUK and WÓJTOWICZ 2013) – 78.

Epiphytes are the most numerous habitat groups in cities and towns of Poland (MATWIEJUK and KOROBKIEWICZ 2012a). Among the habitat groups occurring in the urban landscape of Sokółka the greatest differentiation was demonstrated for epiphytes (53 species). Their records come from the bark of trees growing along of alone the roads, in the parks, cemeteries, squares and forest. In comparison with other towns of Podlasie (MATWIEJUK and KOLANKO 2007, MATWIEJUK 2008, 2009a,b, 2011, MATWIEJUK and KOROBKIEWICZ 2012b) where studies on diversity of lichen species have been carried out the highest diversity of epiphytic lichens was recorded in Bialowieza (66 epiphytic lichens). The poorest epiphytic lichen biota (43 species) was determined in Drohiczyn (MATWIEJUK 2009a). In other towns of Podlaskie voivodeship have been monitored, only 44–57 epiphytic lichen species have been recorded, e.g. 44 species in Narew (MATWIEJUK and KOROBKIEWICZ 2012b), 47 in Mielnik (MATWIEJUK 2008), and 57 in Boćki (MATWIEJUK 2009b).

The corticolous group of lichens comprises nitrophilous, coniophilous and heliophilous lichens, mainly from the genera *Physcia, Physconia, Phaeophyscia, Xanthoria*. Bark of roadside and free-standing trees, as well as phorophytes growing in parks, cemeteries, squares, orchards, seem to create favorable habitats for many epiphytes in towns (MATWIEJUK 2007, 2008, 2009a,b, 2011, MATWIEJUK and KOLANKO 2007, MATWIEJUK and WÓJTOWICZ 2013).

The distribution of epiphytes in towns depends on the species of phorophytes. The most common tree species in the built-up area of Sokółka *Acer platanoides, Tilia cordata, Fraxinus excelsior* are characterized by the highest numbers of epiphytic species: 39, 37 and 27 species accordingly. Epiphytic diversity was lower on phorophytes which mainly occur in centrum of many towns (MATWIEJUK and KOLANKO 2007, MATWIEJUK 2008, 2009a,b, 2011, MATWIEJUK and KOROBKIEWICZ 2012b). The lichens growing on trees along the streets and the roads with heavy traffic may indicate that tree bark was heavily polluted by dust.

In towns, data about species growing on anthropogenic substrates rich in calcium carbonate (e.g., walls of farm buildings, wells, bridges, and posts) (KUBIAK 2005, MATWIEJUK and KOLANKO 2007, MATWIEJUK 2008, 2009a,b, 2011, MATWIEJUK and KOROBKIEWICZ 2012b) indicate a positive effect of urban activities expanding potential habitats for lichenized fungi. Among them, calciphilous species or lichens that tolerate calcium carbonate, e.g., *Calogaya decipiens, C. pusilla, Myriolecis albescens, M. dispersa, Xanthoria parietina*, as well as nitrophilous species from the family Physciaceae (e.g. *Phaeophyscia*

orbicularis, P. nigricans, Physcia adscendens, P. caesia, P. dubia, P. tenella are frequently observed). In urban areas, epilythes colonize isolated stones in open areas, also when they are a part of man-made constructions and anthropogenic substrates. Some interesting records of lichens are known from gravestones and crosses, especially old and not renovated, and cemetery fences (MATWIEJUK 2009b). Old gravestones from the nineteenth century in the village of Bociek (NE Poland) have been colonized by 28 species (MATWIEJUK 2009b). In Sokółka, on old Jewish cemetery, on matzevas grows rare species, e.g. *Candelariella coralliza, Xanthopramelia loxodes, X. verruculifera.*

Terricolous lichens seem to play only a minor role among lichenized fungi growing in towns and city. There is a limited amount of information about their diversity or their occurrence in these places, and therefore it is difficult to find out species associated with the urban landscape. In towns terricolous lichens grow in forest and fallow lands, mainly on periphery of the towns. Species of genus *Cladonia, Peltigera* are dominated (MATWIEJUK and KOLANKO 2007, MATWIEJUK 2008, 2009a,b, 2011, MATWIEJUK and KOROBKIEWICZ 2012b).

In towns, among atypical substrates occupied by lichens are, e.g. metal constructions, eternity roof slates, papa, plastic, rubber (MATWIEJUK and KOLANKO 2007, MATWIEJUK and KOROBKIEWICZ 2012b). In Narew (MATWIEJUK and KOROBKIEWICZ 2012b), seven lichen species – *Candelariella aurella, Myriolecis albescens, M. dispersa, Phaeophyscia orbicularis, Physcia caesia, P. dubia* and *Xanthoria parietina* were recorded on old abandoned tyres.

Numerous studies conducted in towns revealed also protected and threatened and species (e.g. MATWIEJUK and KOLANKO 2007, MATWIEJUK 2008, 2009a,b, 2011, MATWIEJUK and KOROBKIEWICZ 2012b). Most of them have been put on the red list of lichens of Poland (CIESLIŃSKI et al. 2006) in the endangered categories EN, NT, and VU. The most threatened habitat group in towns are epiphytes.

The occurrence of lichens in habitats created by human activities is associated with their environmental requirements and morphological, chemical and physiological considerations of these organisms (cf. FAŁTYNOWICZ 1992). My studies have shown a higher degree of differentiation among crustose lichens found in certain types of land use in the town. The crustose lichens in city fall mainly in the epilithic lichen biota. A higher share of narrow foliose lichens was marked in the green area and periphery. This may be related to the fact of the composition of this group mainly by nitrophilous, coniophilous, heliophilous and xerophilic lichens of genus *Physcia*, *Physconia*, *Phaeophyscia* and some *Xanthoria* particularly associated with urban areas. A higher share of foliose lichens in parks and cemeteries is due to the favorable impact of higher intensity of light reaching the lower parts of the trunks of trees growing in their areas compared to phorophytes of forest communities (DIETRICH and SCHEIDEGGER 1997).

Conclusion

1. Sokółka is characterized, as compared to others towns of Podlasie, by a small number of lichen taxa, smaller number of protected and threatened species as well a lower number of locally rare taxa (recorded in single stands).

2. The biota is dominated by epiphytes – 53 species, including 32 found only on the bark of trees.

3. The richest lichen biota is located in green areas.

4. The lichen biota of Sokółka includes of a large group of lichens typical of urban areas, including nitrophilous, coniophilous, heliophilous and calciphilous species.

Translated by Anna Kuzia

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CHANGES IN POPULATION OF SPOTTED SOUSLIK *SPERMOPHILUS SUSLICUS* IN EASTERN POLAND

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K e y w o r d s: spotted souslik, localities, size of population, threats, protection.

A b s t r a c t

Spotted souslik is one of the most endangered mammal species in Poland. Over the last few decades of the 20th century its population gradually decreased due to the influence of natural and anthropogenic factors: degradation of species habitats and reduction of their acreage. The aim of the study is to examine changes in the population of spotted souslik in eastern Poland, against threats to the species and implemented conservation measures. In the last decade, their population has achieved relative stability. However, despite similar population, the changes of individuals in particular colonies are very significant. Populations of several hundred individuals in favourable habitats were able to increase their numbers, even to the limits of the habitat capacity, and maintain it. Dynamic growth of the artificially created population (Świdnik) has led to overcrowding the colony, which resulted in its total collapse. On the other hand, small populations even in good habitat conditions are not able to recreate.

ZMIANY LICZEBNOŚCI POPULACJI SUSŁA PEREŁKOWANEGO *SPERMOPHILUS SUSLICUS* W POLSCE WSCHODNIEJ

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S ł o w a k l u c z o w e: suseł perełkowany, rozmieszczenie, liczebność, zagrożenia, ochrona.

A b s t r a k t

Suseł perełkowany należy do najbardziej zagrożonych gatunków ssaków w Polsce. Przez ostatnie kilkadziesiąt lat XX w. jego liczebność sukcesywnie malała pod wpływem czynników naturalnych i antropogenicznych. Należały do nich głównie degradacja siedlisk sprzyjających bytowaniu gatunku i zmniejszenie ich areału. Celem pracy jest zbadanie zmian liczebności populacji susła perełkowanego we wschodniej Polsce na tle zagrożeń tego gatunku oraz realizowanych działań ochronnych.

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W ostatnim dziesięcioleciu liczebność populacji osiągnęła względną stabilizację. Jednak mimo zbliżonej liczebności ogólnej gatunku, zmiany liczby osobników w poszczególnych koloniach są bardzo duże. Populacje liczące kilkaset osobników w sprzyjających warunkach siedliskowych były w stanie zwiększyć swą liczebność, nawet do granic pojemności siedliska, i ją utrzymują. Dynamiczny rozrost sztucznie utworzonej populacji (Świdnik) doprowadził do przegęszczenia kolonii, co skutkowało całkowitym załamaniem liczebności. Z kolei małe populacje nawet w dobrych warunkach siedliskowych nie są w stanie samodzielnie się odrodzić.

Introduction

Spotted souslik (*Spermophilus suslicus*) is a small rodent, similar to a squirrel in shape and size (Figure 1). Sousliks live in underground burrows, which are for them shelters, places of reproduction and hibernation. They form colonies, but may also occur in dispersion. Sousliks are herbivores, but also benefit from the animal food. Sousliks hibernate in the autumn-winter period, during which many of them die (50–60%). After awakening they start the heat and beget 3–8 youngs. Sousliks live up to 5 years (MĘCZYŃSKI 1991, PISKORSKI 2004, MĘCZYŃSKI et al. 2008b, PRÓCHNICKI 2008a).

Fig. 1. Spotted souslik *Spermophilus suslicus* (K. Zub)

Spotted souslik is an animal of open areas, it inhabits steppes. The agricultural landscape let it adapted to the new conditions. In Poland, it exists in vast areas of dry meadows, pastures, perennial fallow lands, wastelands, unploughed sections of fields, on the field roads, roadsides, grassy airports. Its sites are mainly found in soils created on loess, much less on sand or sandy-clay

and limestone (MĘCZYŃSKI 1991, PISKORSKI 2004, GRĄDZIEL 2008). The best living condition for souslik is low grass pasture where the vegetation is eaten/browsed by grazing animals. Ryegrass pastures create optimal conditions for sousliks – low grass does not limit their visibility, makes it easy to move, and if necessary, escape to the burrow. Sousliks have many natural enemies. They are both mammals and birds. The mortality caused by predators is high; it mainly affects youngs (PISKORSKI 2004, PRÓCHNICKI and STYKA 2008).

Spotted souslik is an Eastern European species, typical of the continental steppe – its colonies might be found from the Volga River in Russia, through Ukraine and Moldova to the Black Sea and the mouth of the Danube River in the south (ZAGORODNYUK et al. 2008, PRÓCHNICKI 2008a, SHILOVA et al. 2010, SHILOVA 2011). Its largest population is located in Ukraine and Russia, the smaller ones are in Moldova, Belarus and Poland. The western border of the species runs through the south-eastern Poland. Polish sites of spotted souslik in the eastern Lublin Region are the only ones within the European Union. It can be assumed that this species was very common in the Lublin Region in the past. After the agricultural landscape was formed, it survived as a relict animal (SURDACKI 1963, PISKORSKI 2004). Souslik populations in Poland are part of the isolated, insular range covering Volhynian Upland in the central-western Ukraine (GŁOWACIŃSKI and MĘCZYŃSKI 2001). In Poland, there are 6 cohesive colonies, in the south-eastern part of the Lublin Upland and Roztocze. The westernmost site of spotted souslik is an introduced colony in Świdnik – totally detached and spaced approx. 70 km from the area of "compact" occurrence (PISKORSKI 2004, PRÓCHNICKI 2008b). It occurs in dispersed midfield sites away from compact colonies. Its population is difficult to determine.

Spotted souslik is one of the most endangered mammal species in Poland. The story of its protection dates back to 1982, when the first reserves Hubale and Gliniska were created to protect this rare animal, in the following years another reserves were created: Popówka in 1988, Suśle Wzgórza and Wygon Grabowiecki in 1995. Since 1984, spotted souslik has been under strict species protection; currently according to the Nature Conservation Act of 16 April 2004 (Journal of Laws No. 92 item 880, as amended) – it is a species that requires active protection. It is also protected in the framework of the Bern Convention (1979) (Appendix II). Polish sites of spotted souslik under the Habitat Directive (1992) (Annex II and IV) are protected within the European Natura 2000 network. In the EU, souslik has the status of priority species.

Populations of spotted souslik were subject of numerous studies, mainly in Russia, Ukraine and Poland. These studies were focused on the species and the diversity of habitat (ERMAKOV et al. 2002, TCHABOVSKY et al. 2005, SHILOVA et al. 2010, SHILOVA 2011, SLIMEN et al. 2012). Diseases of species and genetic aspects are well described (SZCZURKOWSKI 1999, ERMAKOV et al. 2002, GONDEK

et al. 2006, BIEDRZYCKA and KONOPIŃSKI 2008, BIEDRZYCKA et al. 2011, KLOCH and BAJER 2012, SLIMEN et al. 2012). There are also studies related to the warning sound issued by spotted sousliks (VOLODIN 2005, MATROSOVA et al. 2012).

The aim of the study is to examine changes in the population of spotted souslik in eastern Poland, against threats to the species and implemented protective measures.

Materials and Methods

Analysis of changes in population of spotted souslik in Poland was carried out on the basis of published and unpublished data. It proceeded in two stages. Firstly, historical data were analyzed. The oldest studies from the 19th and early 20th century, contain only general information on the observed occurrence of this species in some area of south-eastern Poland (STRONCZYŃSKI 1839, TACZANOWSKI 1855, WAŁECKI 1866, TENENBAUM 1913, SKURATOWICZ 1948) and does not represent a useful material for analysis of changes in the population. The first historical data on population of spotted sousliks have been obtained from SURDACKI'S studies (1956, 1963). The author applied the method of questionnaire with subsequent field verification, as described in 1956. These data are only approximate (SURDACKI 1956). Subsequent data come from an inventory conducted in the years 1979–1985 by MĘCZYŃSKI (1991, 1992). After interviews with the inhabitants he made direct field observations. These activities were focused on establishing places of the species. The author introduced the definitions of: compact colony and midfield colony. However, the information is inaccurate: "Compact colonies [...] usually expect from a dozen to hundreds, or even tens of thousands of individuals" (MĘCZYŃSKI 1992, p. 255). Unfortunately, the accuracy of the results of these studies is questionable. Next studies are expert reports which results were not published (PRÓCHNICKI et al. 2008a). Since 2000 when the program: "Protection of spotted souslik sites..." was implemented, constant monitoring of the spotted sousliks population within compact colonies has been carried out. The results of this monitoring were not published. Data of our detailed analysis are the results of the spotted souslik population in years 2006–2015 obtained from various sources:

1. Zamojskie Wildlife Society – "Inventory of spotted souslik in Poland 2006–2008" (MĘCZYŃSKI et al. 2006, MĘCZYŃSKI et al. 2007, MĘCZYŃSKI et al. 2008a, for: *Forum dyskusyjne Przyroda*... 2016).

2. Regional Directorate of Environmental Protection in Lublin (RDEP) – unpublished data for the years 2009–2015, available to the authors.

3. Airport Świdnik SA – Report on the state... (MĘCZYŃSKI et al. 2013, MĘCZYŃSKI et al. 2015), Report on the introduction... (MĘCZYŃSKI et al. 2014).

The methodology used by the authors of the above mentioned studies is described in: http://siedliska.gios.gov.pl/pdf/publikacje/przewodnik_metodyczny_zwierzeta_1.pdf. and MĘCZYŃSKI et al. (2010). Two methods were used: method I – counting borrows after clogging of the inlet holes; method II – counting burrows without clogging of the inlet holes. Each method may be option 1 – the whole area inhabited by the sousliks or on the test surface – option 2. Using option 2 tests are conducted in transects, and the results are carried out statistically.

The collected data have been developed in graphical and statistical way.

Results and Disccusion

The oldest mention of the spotted souslik occurrence in Poland dates back to the mid-19th century, when this species was observed in the vicinity of Zamość, Chełm, Szczebrzeszyn and Hrubieszów (STRONCZYŃSKI 1839, TACZANOWSKI 1855, WAŁECKI 1866). Just as the studies from the first half of the 20th century, they contained only a reference to the occurrence of the species (TENENBAUM 1913, SKURATOWICZ 1948).

The first detailed data on the population of spotted souslik in Poland date back to 1950's. As a result of an inventory conducted in 1953–1954, SURDACKI (1956) found 153 sites of spotted sousliks (132 active), which together counted 70 thousand of animals. All the sites were located in the south-east of Lublin (generally in poviats: tomaszowski, zamojski, hrubieszowski). By 1961, the population had dropped by more than a half – only approx. 24 thousand individuals at 81 sites were reported (the disappearance of more than 40% of sites). At the same time the number of large colonies decreased from 20 (19) in 1954 to just 8 in 1961. Including 2 new ones (SURDACKI 1963) – Figure 2*a* and Figure 2*b*. Decline of the species is partly due to natural causes. In spring of 1957 and 1958 there were very heavy rainfalls which caused flooding of souslik's burrows with youngs (SURDACKI 1963). But the most important reason for the decline of the spotted souslik population was the intensification of agriculture, changes in agricultural techniques and industrialization of the area. This has led to the disappearance of favorable habitats. Large tracts of lands which used to be fallow lands and pastures have been converted into arable lands used permanently, lands were merged in many hectares of cultivation (reducing the length of midfield roads). Chemical pesticides and mechanization of agriculture were also used in a large scale, which resulted in the total destruction of many colonies (SURDACKI 1963, PISKORSKI 2004,

BIEDRZYCKA 2009). This has led to the dismemberment of the spotted souslik natural area, isolation of individual colonies and increase of the distance between them.

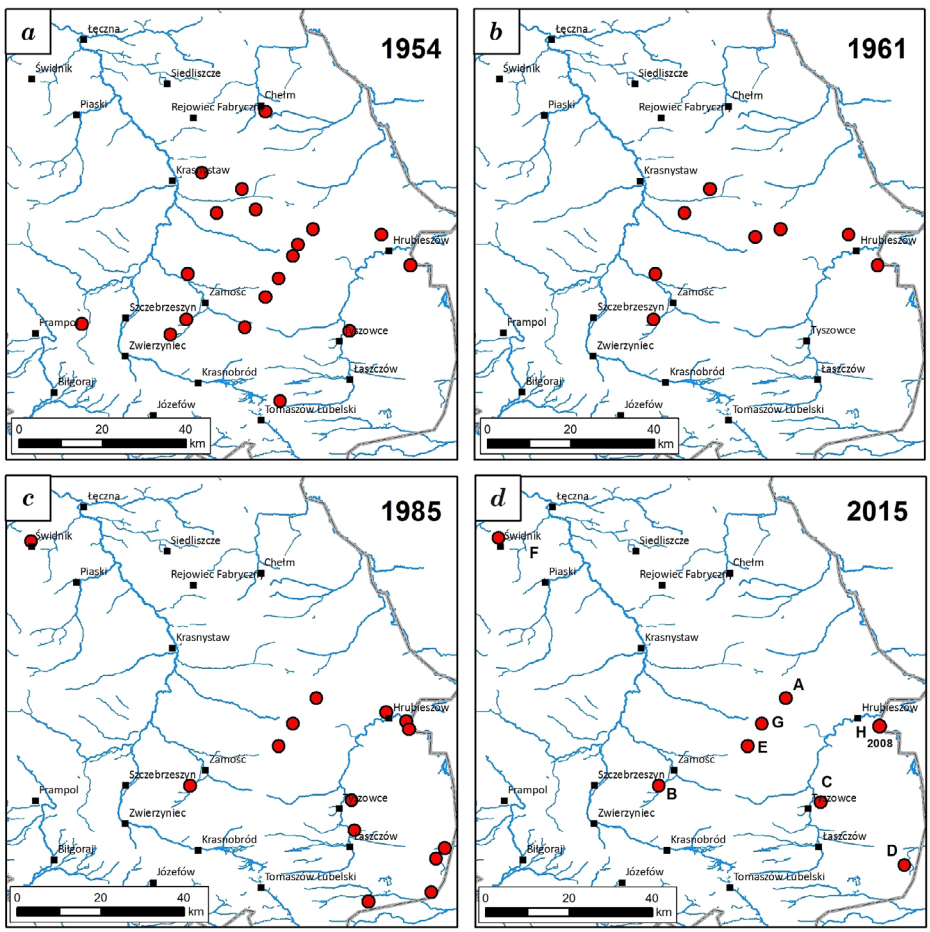

Fig. 2. Distribution of spotted souslik compact colonies in Poland: *a* – Surdacki (1956); *b* – Surdacki (1963); *c* – Męczyński (1992); *d* – RDEP (unpublished data 2015)

Another inventory conducted in the years 1979–1985 by MĘCZYŃSKI (1991, 1992) showed a decrease in the number of spotted souslik sites by 61% in relation to the number of sites registered by SURDACKI (1963). Męczyński writes about the existence of 32 sites in this period: 12 (11) cohesive colonies and 20 midfield colonies. The basic known cause of the sites reduction was further adverse effects on the spotted souslik habitats: mainly plowing the

pastures and conversion into cropland or pasture and wasteland afforestation (MĘCZYŃSKI 1991, 1992). In 1989, two large cohesive colonies of spotted sousliks were found in Zamość voivodeship (Chochłów and Myców), while in 1990, a large colony at the airport in Świdnik near Lublin was discovered (MĘCZYŃSKI 1992). This colony, estimated at approx. 1.5 thousand of individuals, appeared suddenly, out of the reach of compact occurrence and is the result of bringing sousliks by a human. Sousliks had never been seen as far west sites. As a result of these findings it can be assumed that in the late 80's there were 14 cohesive colonies of spotted souslik in Lublin Region (Figure 2*c*). Further inventories showed in the late 90's the existence of only 7 cohesive colonies and only 18 midfield sites (PISKORSKI 2004). At the beginning of the 90's there was the collapse of the cattle and sheep rearing, and thus degradation or reduction of pasture acreage. Habitats most relevant to sousliks were overgrowing with herbaceous vegetation and thickets of trees and shrubs, which led to the disappearance of food base for sousliks. Indirect adverse effect of reducing the area of souslik habitats was the internal-population increase in mortality resulting from overcrowding in the descending area. The following habitat fragmentation and disruption of communication between the sites led to the isolation of the subpopulations. Impossibility of animals migration from one colony to another causes a reduction of genetic variation which increases the susceptibility of parasites and viral diseases (MEAGHER 1999, RUSHTON et al. 2000, BIEDRZYCKA 2008, BIEDRZYCKA and KONOPIŃSKI 2008). To sum up – in the second half of the 20th century the number of spotted souslik sites decreased by 90%. The number of animals within individual colonie also declined significantly.

At the beginning of the 21st century the largest site of the spotted sousliks' was a colony in Świdnik, which represented about 90% of Polish population (GONDEK 2007). In addition, spotted sousliks occurred in six cohesive colonies near Zamość. Four of them are reserves: Hubale, Popówka, Wygon Grabowiecki and Suśle Wzgórza; an ecological ground – Błonia Nadbużańskie and the pasture near Tyszowce village (currently planned reserve Pastwiska nad Huczwą) – Figure 2*d*. In addition, sousliks were found scattered at several sites in Zamość Region (GONDEK 2004, PISKORSKI 2004).

On the basis of the collected data, a detailed analysis of the sousliks population for the years 2006–2015 was carried out. In 2006, there were 10.5 thousand individuals in monitored cohesive colonies (Figure 3). In the years 2008–2009, the number of populations dropped significantly to less than 4.5 thousand individuals. Next years are characterized by the restoration of the species population to 7.5–9.3 thousand. Recent data inform about 8 thousand sousliks in 2015 (Figure 3). The trend line for the analyzed decades indicates statistical stabilization of the population for that period. Despite the fact that

between 2006 and 2015 the similar total number of sousliks was reported, it consists of individuals living in different locations. While in 2006, the vast majority of species (9800 individuals, >90% of the population) were associated with anthropogenic colony at the airport in Świdnik, then in 2015 the population of sousliks living in colonies Popówka and Suśle Wzgórza was dominating (respectively: 71.5% and 23%).

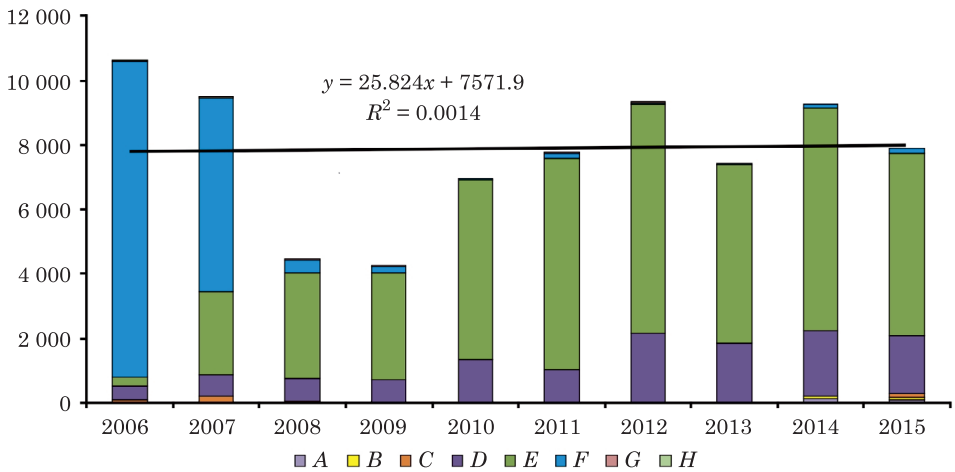

Fig. 3. The number of spotted souslik populations in compact colonies in the years 2006—2015 (*A* – Gliniska, *B* – Hubale, *C* – Pastwiska nad Huczwą, *D* – Suśle Wzgórza, *E* – Popówka, *F* – Airport Świdnik, *G* – Wygon Grabowiecki, *H* – Błonia Nadbużańskie)

Predominant in population in 2006 colony at the Świdnik Airport is an example of "temporarily" successful, although unplanned introduction of spotted souslik. It was created as a result of bringing dozens of individuals from Chochłów (now reserve Suśle Wzgórza) and releasing them into a favorable habitat in the 1970's (PRÓCHNICKI et al. 2008a). Since 2006 spotted souslik population in Świdnik have plummeted to only a few individuals in 2010 (Figure 4*f*). The reason for this situation was probably an unnatural overcrowding. Another factor threatening the population was its isolation. It has led to restrictions and so small ("founder effect") genetic variation within the colony, which was the subject of detailed studies (GONDEK 2004, BIEDRZYCKA 2008, BIEDRZYCKA and KONOPIŃSKI 2008). Each decline even further reduced genetic variability of the population through genetic drift (ERMAKOV et al 2002, GONDEK 2007, PILOT 2009, ŁOMNICKI 2009). In order to rebuild the population of sousliks in Świdnik, 150 and 60 individuals from the reserve Popówka were introduced in 2011 and 2014. In 2015, the population amounts to 152 individuals (MĘCZYŃSKI et al. 2015).

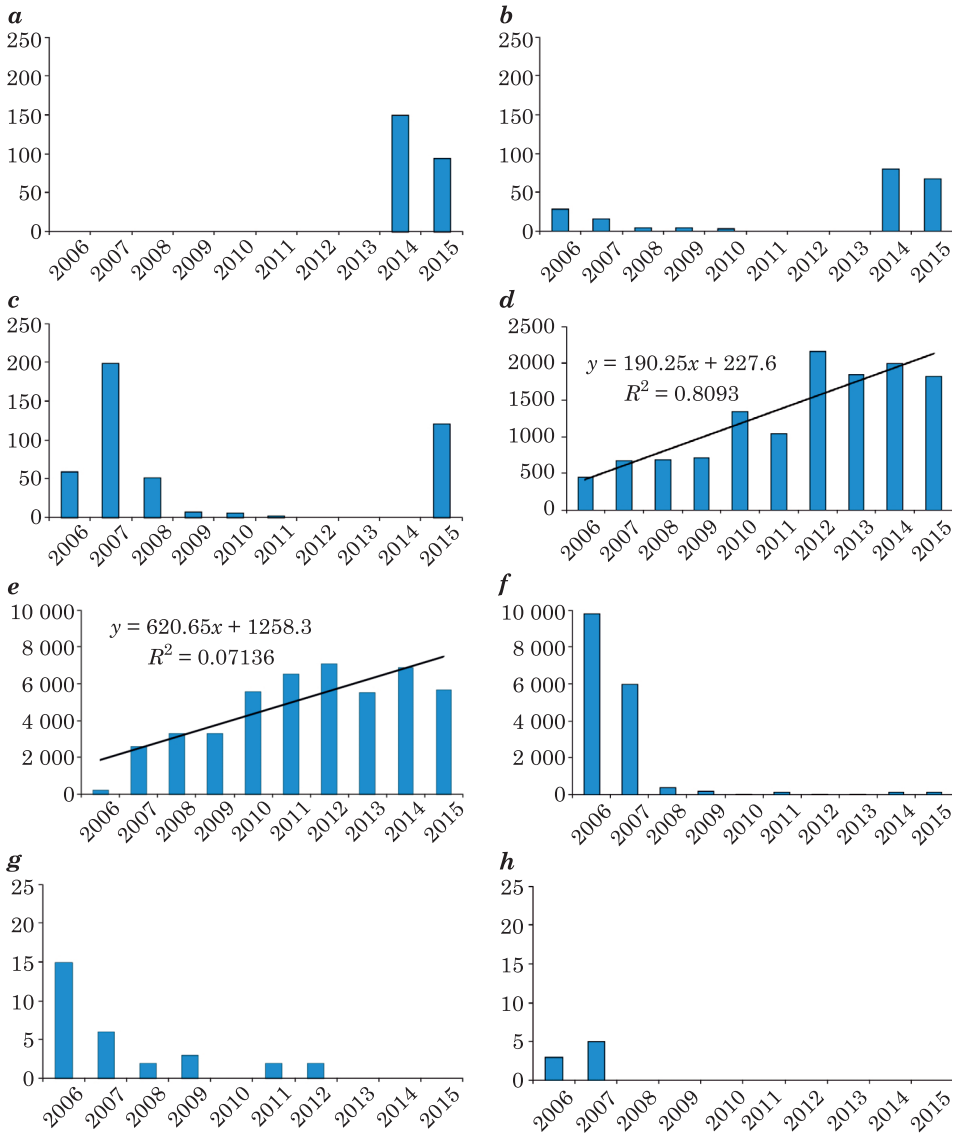

Fig. 4. Population of spotted sousliks in compact colonies in the years 2006–2015: *a* – Gliniska; *b* – Hubale; *c* – Pastwiska nad Huczwą; *d* – Suśle Wzgórza; *e* – Popówka; *f* – Airport Świdnik; *g* – Wygon Grabowiecki; *h* – Błonia Nadbużańskie

In contrast to the declining population of sousliks at the Świdnik Airport number of species in the reserves Popówka and Suśle Wzgórza was gradually increasing (Figure 3). In Popówka reserve in the years 2006–2015 the population of sousliks increased from 249 to more than 5.5 thousand, exceeding

7 thousand individuals in 2012 (Figure 3*e*) – it determined the capacity of the reserve. Data from the year 2006 (249 individuals) should be treated with caution, as surprising is the fact of 10-fold increase in the number of sousliks year-on-year, to 2577 individuals in 2007 (MĘCZYŃSKI et al. 2006, MĘCZYŃSKI et al. 2007). At the same time in the reserve Suśle Wzgórza there was an increase of the population from 449 to 1820 individuals at present, with a maximum ratio amounting to 2164 individuals in 2012 (Figure 3*d*). The increase of the sousliks population in these two sites is probably largely the result of active protection. Since 2000, the following programs have been implemented: "Conservation of spotted souslik habitats in Zamość Region/in Poland", "Conservation of natural habitats and species in the Natura 2000 sites in the Lublin voivodship" and "Implementation of protection assignments for the Natura 2000 sites and nature reserves in the Lublin voivodship" under the supervision of the Regional Directorate of Environmental Protection (RDEP) in Lublin (PRÓCHNICKI et al. 2008b, RDEP data). The main aim of these activities is to increase the number of animals by restoring the optimal habitat conditions for the sousliks. Conservation activities such as grazing and/or systematic mowing of the vegetation, cutting thickets of trees and shrubs, turf reclamation by reseeding plants preferred by sousliks and fertilization, which were carried out under the project, allowed for the restoration of grazing character of the protected objects (RDEP data).

After 2006, at the sites Pastwiska nad Huczwą, Hubale and Wygon Grabowiecki a trend of decline is indicated, which led to the disappearance of the population existing there in 2013 (Figure 4*c*, *b*, *g*). This happened despite the measures implemented to improve the habitat conditions. The reason for the extinction could be too small population (several-dozen of individuals), insufficient for its rebirth. It is assumed that the minimum number of individuals required to rebuild the population of sousliks is 150 individuals (MĘCZYŃSKI et al. 2014). Another factor contributing to the loss of such a small population could be adverse weather conditions in winter 2012/2013 and rainy period of heat (personal communication from RDEP). As part of the ongoing programs, attempt to restore populations of sousliks was undertaken by reintroductions of sousliks in 2014 in the reserves Hubale (80 individuals) and Gliniska (150), where the sousliks were extinct in the early 90's, and in the nature reserve Pastwiska nad Huczwą in 2015 (120 individuals) – Figure 4. The animals were obtained from the Popówka site. Today, the worst situation is in the reserve Wygon Grabowiecki where since 2013 the population has not been existing. Unfortunately there is no current data to the site Błonia Nadbużańskie where sousliks died out in 2008. Since 2009 the monitoring has not been carried out there.

Conclusions

The last sixty years show that Polish population of spotted souslik is highly unstable. Since the 1950's, when it was estimated at approx. 70 thousand individuals, number of species has been gradually decreasing to about 10 thousand today. This was due to natural factors, and – especially – anthropogenic ones. Conservation activities in the last decade has led to a relative stabilization of souslik population in the Lublin Region. Regardless of a similar total population of individuals of the species, changes in individual colonies are very large and move in different directions. Populations numbering several hundred individuals in favorable habitat conditions are able to increase their numbers, even to the limits of the capacity of the habitat, and maintain it (Popówka, Suśle Wzgórza). In contrast, the dynamic growth of the artificially created population in favourable habitat conditions has led to overcrowding of the colony (Świdnik). Along with a small genetic variability it resulted in a total collapse of the population. On the other hand, small populations, numbering from a few to several dozen individuals, even in the good habitat conditions are not able to be reborn (Pastwiska nad Huczwą, Hubale i Wygon Grabowiecki). To the restoration and maintenance of historic sites of spotted souslik in Poland, further action within the framework of active conservation is needed. Apart from maintaining habitats in an optimum state for a species, to reproduce small or extinct populations subsequent reintroductions are necessary. To avoid inbreeding depression and increase the genetic variability of the Polish population of sousliks the best solution is to introduce the individuals from Ukraine, where sousliks are still in a good condition. It is hoped that consistent measures will save Polish population of spotted souslik from annihilation.

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DEVELOPMENT OF DRWĘCKIE LAKE IN OSTRÓDA FOR TOURIST AND RECREATIONAL PURPOSES, AND ITS IMPACT ON THE BURDEN TO THE NATURAL ENVIRONMENT IN THE SHORELINE ZONE

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K e y w o r d s: recreation, tourism, shoreline burden, land development for tourism, lake.

A b s t r a c t

Our analysis deals with the land development and management for tourist and recreational purposes around Drwęckie Lake, a water body lying in the limits of the town Ostróda. A lot of tourists and residents in summer season can be attributed to the spatial management, a wide range of hospitality facilities and many opportunities to practice water sports and to hold mass events. Another aspect we analyzed was the influence that these various forms of development for tourism and recreation could have on the natural environment of Drwęckie Lake. To this aim, the shoreline burden indicator (K) values and the lake's burden class were calculated. It has been concluded that both land and water shore zones are considerably loaded due to the densely developed space and increasingly intensive tourist and recreational activities. Current situation can lead to excessive degradation of the lake's water and depreciation of the tourist value of the entire area.

ZAGOSPODAROWANIE TURYSTYCZNO-REKREACYJNE JEZIORA DRWĘCKIEGO NA TERENIE OSTRÓDY – WPŁYW NA OBCIĄŻENIE STREFY BRZEGOWEJ

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Abstrakt

Przeanalizowano zagospodarowanie turystyczno-rekreacyjne Jeziora Drwęckiego w Ostródzie. Sposób zagospodarowania, bogata oferta gastronomiczna i noclegowa oraz atrakcje związane z możliwością uprawiania sportów wodnych i organizowania imprez masowych przyciągają w sezonie letnim wielu turystów i mieszkańców miasta. Zbadano także wpływ form użytkowania turystyczno-rekreacyjnego na środowisko przyrodnicze Jeziora Drwęckiego, wyznaczając wskaźniki stopnia obciążenia strefy brzegowej (*K)* oraz klasy obciążenia jeziora. Stwierdzono, że obydwie strefy – lądowa oraz wodna – są w znacznym stopniu obciążone z powodu intensywnego zagospodarowania przestrzeni oraz intensyfikację różnorodnych form użytkowania turystycznego i rekreacyjnego. Może to być przyczyną nadmiernej presji antropogenicznej i wpływać negatywnie na przeobrażanie obszarów zlokalizowanych wokół Jeziora Drwęckiego. Obecna sytuacja może doprowadzić do nadmiernej degradacji wód jeziora i w efekcie obniżyć walory turystyczne tego obszaru.

Introduction

Lakes can be an attractive tourist destination not only because of the quality of lake water or their size (DUDA-GROMADA et al. 2010, REMENYIK et al. 2013). What matters is also the visual quality of a lake's surroundings, which frequently depends on buildings or woods on the lake's shores (FURGAŁA-SELEZNIOW et al. 2012, POTOCKA 2013). For the recreational use, the most valuable are lakes with clean water, gently sloping shores, sandy bottom and lying in an afforested catchment (KOŻUCHOWSKI 2005, SERAFIN et al. 2014, TANDYRAK et al. 2016). Another important aspect is the tourist and recreational development of the adjacent land, which can attract both local residents and visitors (DUDA-GROMADA et al. 2010, HALL 2010, RYAN et al. 2010, HAKUĆ-BŁAŻOWSKA and TURKOWSKI 2013).

The use of lakes for tourism and recreation often creates negative influences on the environment, giving rise to conflicting situations between the hospitality industry and environmental protection (BNIŃSKA 2000, DUNALSKA et al. 2015, TANDYRAK et al. 2015). Excessive numbers of tourists in areas around water bodies, which have a specific tourism capacity, stimulates an anthropogenic pressure and causes degradation of nature (CURTIS 2003). The adverse impact of accumulated tourist traffic arises from such events as grass trampling and burning, ground damage by cars, littering, atmospheric pollution, for example with exhaust fumes (KRUKOWSKA and KRUKOWSKI 2013). All these negative circumstances threaten both plants and animals. When the number of visitors coming to a given place seems exaggerated, tourists and residents feel uncomfortable, which can trigger outbursts of aggression (PUCZKÓ and RÁTZ 2000, SUPREWICZ 2008, PAWLIKOWSKA-PIECHOTKA 2009).

The land development for the tourism industry leads to transformations of the lithosphere (FURGAŁA-SELEZNIOW et al. 2011, PASEK and NOWAK-ZALESKA 2011), changes in the hydrosphere (quantity and quality of waters) (SKRZYP-

CZAK et al. 2011), increased traffic and noise, higher emission of waste (SIKORSKA-WOLAK 2004) and even climate changes (PATTERSON et al. 2006).

SKŁODOWSKI (2009) lists numerous factors connected with water tourism which have an adverse impact on water environment and woods. They include pollution of the habitats of fish and invertebrates caused by two-stroke engines, which emit to water between 10 to 20% of the used diesel oil and fuel mixture (nitrogen oxide, hydrocarbons, carbon, sulphur oxides, lead compounds, PAHs), chemical poisoning of animals due to spills of oil and fuel while filling up cars (lead(IV) oxide, ethyl bromide, short- and long-chain hydrocarbons, dichloroethane, phosphorus, zinc, sulphur oxides, etc.), water contamination due to discharge of wastewater with chemical compounds to lake waters rather than at marinas (about 25% of boat users), introduction of detergents to lake waters by swimmers who apply sun protection creams or persons who wash up dishes in lake waters using detergents.

Another source of negative impact is the creation of waves and turbulences, responsible for the erosion of the lake bottom and shores as well as the soil leaching around tree roots, which may then fall into the water. Defects observed along the shores are attributed to a variety of causes, for example anchoring of boats (BRAMWELL and POMFRET 2007, KURLETO 2014), bathing, hiking, camping or digging holes in the ground serving as earth closets, digging steps in the ground for easier access to the lake when fishing, damaging plants with oars or boat propellers, frightening animals with the sounds and views of moving boats. Finally, there is a notable negative influence of land engineering, e.g. transformations of shores, construction of embankments, the leveling of ground (SKŁODOWSKI 2009).

Overtly intensive plans for the spatial management of areas around natural water bodies are frequently a cause of excessive pressure and transformations of the natural environment (HAKUĆ-BŁAŻOWSKA and CYMERMAN 2011). As a consequence, a completely transformed area may preclude any tourist or recreational function.

The essence of this study has been to evaluate Drwęckie Lake, in Ostróda, regarding its appeal to tourists and possible use for tourism and recreation. The assessment was followed by an analysis of the effect of land management for tourism and recreation as well as the forms of recreational use available today on the burden to the natural environment in the lake's shoreline zone.

Material and Method

Research object

Drwęckie Lake lies at the latitude 53º42' 57'' N 19 and longitude 55'11'' E in the Mazurian Lake District in Poland, in the catchment of the rivers Drwęca and Vistula. Location of Drwęckie Lake is presented in Figure 1. The lake's surface area is 880.8 ha. There is an islet Ostrów on the lake, covering 10.8 ha. The maximum length and width of the lake are 15,500 and 1,100 m, respectively. The maximum depth is 22.3 m, and the average depth is 5.7 m. The shoreline length is 40,600 m and shoreline development index is 3.86 (CHOIŃSKI 1991, DARMOCHWAŁ and RUMIŃSKI 1996).

Fig. 1. Location of Drwęckie Lake (NE Poland; The Mazurian Lake District)

The southern shores are flat, wooded and waterlogged. To the north, the shores are high and sometimes steep, descending towards the lake. Most of the lake's surroundings are covered in forests, especially in the north and off the northern part of the lake's shoreline called the Samborowska Channel. The bottom is irregular and muddy, same as the slopes of the shoal (WALUGA and CHMIELEWSKI 1996).

According to the 2014 data the lake belongs to class II of degradation sensitivity, which means it is relatively resistant to the impact of its catchment. The lake waters were classified between water quality class III and classless category (*Informator turystyczno-przyrodniczy* 2014).

Methodology

The data collected during the field observations in the spring of 2014 were plotted onto topographic maps (Figure 2) and a satellite map of this area, so as to illustrate the current state of the land management for tourism and recreation around Drwęckie Lake in the town limits of Ostróda. The shore zone was divided into the land and water parts. The land shore zone is the area from the shoreline into the land over a distance of 200 m, and it has been divided into sections 500 m in length along the lake's banks. The water shore zone is the area from the shoreline into the lake, 100 m wide and likewise divided into 500-meter sections along the banks.

The total surface area was determined as well as the areas under different forms of development for the tourist and recreational purposes (planimetric representation – Sokkia Placom KP 90 N planimeter).

Each distinguished area (P_i – area under different types of tourist use) was assigned valuation scores (B_i), which should differentiate between the types and direction of impact on the natural environment, according to the indicators proposed by MIKA (2004) and FURGAŁA-SELEZNIOW et al. (2011). The total area (P_o) of the designated field is a unit valid for the sum of products of the determined valuation scores and the character of a given area. The index of the burden to the natural environment in the lake shore zone (K) was derived from the formula (MIKA 2004):

$$K = \sum \frac{P_i \cdot B_i i}{P_o}$$

K – index of tourism infrastructure burden on the natural environment in the lake shore,
P_i – area under different types of tourist use,
B_i – valuation score,
P_o – reference unit area (total area of designated field).

The calculated value of the shore burden index (K) and lake burden class served to estimate the degree of impact produced by individual forms of tourism and recreation on the natural environment in the shore zone of Drwęckie Lake, in accordance with the guidelines specified in Table 1.

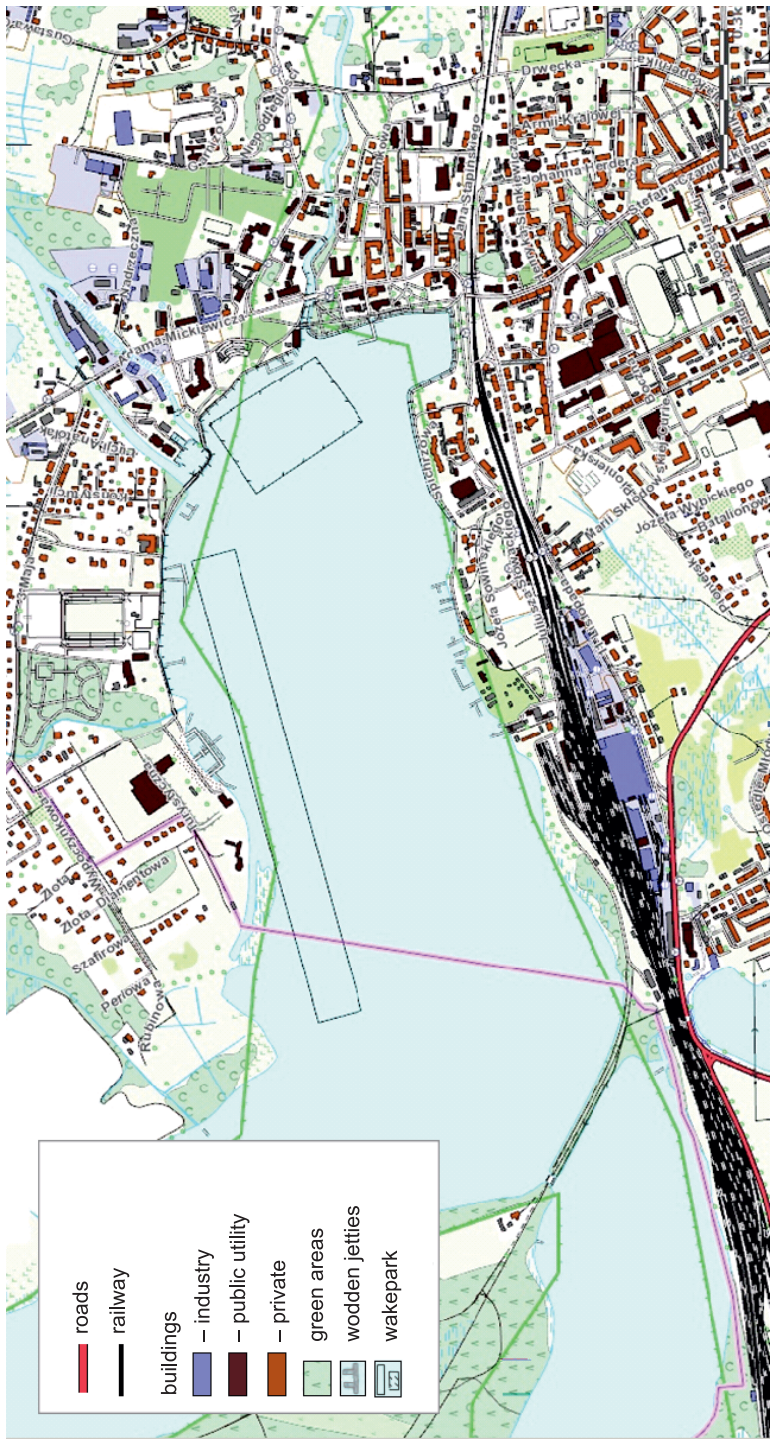

Fig. 2. Topographic map of Drwęckie Lake on the Ostróda area (Geoportal)

Table 1

Class burden indicator of the natural environment for a specific character recreational use of lake's shoreline (MIKA 2004)

Class of lake's shoreline burden	Degree of lake's shoreline burden	Value range of *K* indicator
I	considerable	> 0.1
II	moderate	0.1–0.01
III	slight	< 0.01

K – index of tourism infrastructure burden on the natural environment in the lake shore (shore burden index)

Results

Description of the development and management for tourism and recreation of Drwęckie Lake in the town limits of Ostróda

The field observations carried out in 2014 verified good accessibility of Drwęckie Lake from the western and southern sides, near urbanized areas, where there are numerous foot paths and a bikeway. The shores are well maintained. Litters are almost absent and found only sporadically close to some buildings.

The tourist and recreational development around Drwęckie Lake comprises such facilities as the Marina, the premises of the Ostróda-Elbląg Cruise Company, an amphitheatre, a stadium, the Willa Port Hotel, the Promenada Hotel, many restaurants, a water-ski lift, a caneoing track, a lifeguarded bathing beach, small jetties, a pier, summer cottages, water equipment rentals, a fountain and a playground.

Drwęckie Lake marks the beginning of a cruising trail on the Elbląg Canal. The canal, recently renovated, is equipped with a system of lifts for ships that is unique in the world. In order to surpass a 100-meter difference in water table levels, boats enter carriages which are then pulled over five consecutive inclined planes. The mechanism is powered by the water flow in the canal. In 2012, a Decision of the President of the Republic Poland was passed that instituted the Elbląg Canal as a Heritage Site.

Other popular water trails are the Ostróda-Stare Jabłonki Canal, the John Paul II Trail from Ostróda to Iława, the Drwęca River Trail, as well as the trails connecting Ostróda and Toruń, Ostróda and Tabórz, Ostróda and Idzbark, Ostróda and Elbląg and many others connecting to such lakes as Pauzeńskie, Szeląg Wielki and Szeląg Mały. The section of the trail from Miłomłyn to Ostróda runs through some waterlogged areas, which necessitated the construction of four locks: Miłomłyn (water elevation of 2.8 m),

Zielona (1.4 m), Ostróda and Mała Ruś (1.4 m), which are now an additional technical attraction for tourists (STACHURSKI 2002). The company Żegluga Ostródzko-Elbląska Sp. z o.o in Ostróda, which was founded in 2011, is currently among the best thriving cruise operators in the western part of Mazury.

Drwęckie Lake is an excellent destination for the pursuit of all types of water sports and active pastime. Among the recreational facilities there is a waterski lift, which was installed in 2009. It is 800 m long and can be remote controlled from the shore. The lift can serve 9 users at a time. There is some expensive infrastructure on the shore, for example a building with changing rooms and showers for waterskiers, and an equipment rental. The estimated number of waterskiers and wakeboarders using the lift each season is several thousand. The water lift attracts both amateur and professional athletes who practice water sports. Since 2010, the All Poland Wakeboarding Championships have been held on Drwęckie Lake. In 2014, Ostróda hosted the European Wakeboarding Championships. In 2009, two Olympic-size oar racing tracks (1000 and 500 m) were opened on Drwęckie Lake. Last but not least, there are several boat races taking place in Ostróda, which all attest to the rich tradition of water sports in Ostróda.

A large pier stretching lakeward out from the shore of Drwęckie Lake is the largest construction of this type in Polish inland waters. At the far end, there is a big gazebo and a wooden promenade around it, over the lake waters, which is used for walks, social meetings but also for open-air concerts in the summer. There are benches and some carved wooden statues on the pier. Nearby, there are many cafes and restaurants as well as hotels and hostels, serving needs of all tourists.

A roofed amphitheatre, co-funded by the European Union, was constructed near the lake's shores in 2012. This is the largest roofed amphitheatre in Warmia and Mazury and has become a venue of various artistic and cultural events, including summer shows of cabarets, music concerts, theatrical performances, all drawing crowds of local residents and visitors (for example, the Dance Music Festival Preselection, the Sea Days, the Days of Ostróda, the Stars Olympic Games and supporting concerts, the Ostróda Reggae Festival). In the same year, a municipal fountain with an audiovisual system of colourful lights and musical sounds was built. The fountain's central element is a statue of a fisherman.

Preparations for the Euro 2012 Games in Poland included the construction of a stadium with football pitch and the renovation of Collis Park near Drwęckie Lake. The football pitch was created mainly for playing football matches. It is classified as auxiliary infrastructure. It is equipped with additional sports and recreational facilities and devices, for example two

tennis courts, a climbing wall, a skateboarding ramp and a roofed ice rink. There are also toilets, showers, changing rooms, and rooms for medical and uniformed services. The youngest generation was taken into consideration when restoring Collis Park. There are table tennis tables, a rope park, an open-air gym, fitness paths, a basketball court and a mini golf course.

There is a bathing beach near the park and a hotel. The beach has the most favourable location as it is well exposed to the sun and presents high landscape values. This is a large beach with good access to the lake's shores. It is also easily accessible to visitors, who are offered such infrastructure as changing rooms, toilets, a first aid point, and a water equipment rental. This bathing beach is an example of a developed facility, adapted to seasonal use, with a designated although unguarded bathing area and a jetty (in 2014). There are other water equipment rentals, for example at the Morliny Sailing Marina, the LOK marina or the Sokół Sports Club, which rent equipment to tourists for charge fees.

Indicators defining the degree of impact of tourism on the natural environment of the lake's shore zone

Values of the indicator (*K*) reflecting the load on the lake's shore zone (both land and water) were determined in relation to various types of tourism and recreation activities. Subsequently, classes of the burden to the natural environment in the shore zone were assigned (Table 2 and Table 3). The forms of land development for tourism and recreations identified within the shore zone of Drwęckie Lake in the town limits of Ostróda are presented in Figure 3.

The land and water shore zone of Drwęckie Lake was divided into 7 fields of different surface areas, adding up to 67.723 ha of the land (Table 2) and 32.138 ha of the water shore zone (Table 3).

The highest degree of loading onto the lake's natural environment was detected in fields *5* and *6* (Figure 4), where the dominant land use types are accommodation and active recreation facilities for tourists, which are examples of permanent land development and therefore most strongly stimulate denaturalization of the environment (Figure 3).

In field *6*, where the degree of burden was the highest, the land shore zone *K* index reached 1.09, which corresponds to class I of natural environment load (Table 2, Figure 4). The underlying cause was the presence of sports facilities, such as a stadium and tennis courts. Moreover, much of this part of the lake's shores is occupied by a hotel and three other, smaller guesthouses. There is also Collis Park near the stadium but it is less of a burden than the

Table 2
Evaluation of the influence of various forms of tourism and recreation on the environment of land shore zone of Drwęckie Lake in the town limits of Ostróda

Number of field	Area of land shore zone [ha]	The forms of tourist exploit – area [ha] P_1; P_2; P_3; P_4; P_5 – Symbol of area					Valuation score (B_i) for different kind of tourist impact						
		tourist settlement	Active recreation areas			other recreational	P 1	P 2	P 3	P 4	P 5	K	K_1
		P_1	P_2	P_3	P_4	P_5							
1	8.6950	–	–	–	–	3.6300	–	–	–	–	1	0.420	I
2	9.6550	0.0640	0.0620	0.0560	–	–	5	4	3	–	–	0.080	II
3	7.7260	–	–	0.1000	–	–	–	–	3	–	–	0.040	II
4	13.2210	0.2040	0.3090	0.1100	–	1.5100	5	4	3	–	1	0.430	I
5	8.3140	1.4580	0.0091	0.1100	–	1.1900	5	4	3	–	1	1.060	I
6	10.7180	0.3390	1.8940	0.1200	–	2.0600	5	4	3	–	1	1.090	I
7	9.3940	0.7090	0.6080	0.0900	–	–	5	4	3	–	–	0.660	I
Total	**67.7230**	**2.7740**	**2.8821**	**0.5860**	**0.0**	**8.3900**							

K – shore burden index; K_1 – class burden index

Table 3
Evaluation of the influence of various forms of tourism and recreation on the environment of water shore zone of Drwęckie Lake in the town limits of Ostróda

Number of field	Area of water shore zone [ha]	The forms of tourist exploit – area [ha] P_1; P_2; P_3; P_4; P_5 – Symbol of area					Valuation score (B_i) for different kind of tourist impact						
		tourist settlement	Active recreation areas			other recreational	P 1	P 2	P 3	P 4	P 5	K	K_1
		P_1	P_2	P_3	P_4	P_5							
1	4.9500	–	–	–	–	–	–	–	–	–	–	0.000	III
2	4.7690	–	–	–	0.0314	–	–	–	–	2	–	0.013	II
3	4.8740	—	–	–	–	–	–	–	–	–	–	0.000	III
4	3.7750	–	–	–	0.0074	–	–	–	–	2	–	0.004	III
5	4.7110	–	1.6850	–	0.0091	–	–	4	–	2	–	1.430	I
6	4.2270	–	0.3130	–	0.0070	–	–	4	–	2	–	0.300	I
7	4.8320	–	1.7360	–	0.0041	–	–	4	–	2	–	1.440	I
Total	**32.1380**	**0.0**	**3.7340**	**0.0**	**0.0590**	**0.0**							

K – shore burden index; K_1 – class burden index

other elements of permanent land development. Another example of development for tourism and recreation is the foot and bicycle path along the lake. The water shore zone in this field comprises a jetty and part of a canoe track, which correspond to forms of the recreational use of lake waters – K index reached 0.30 (Table 3, Figure 3).

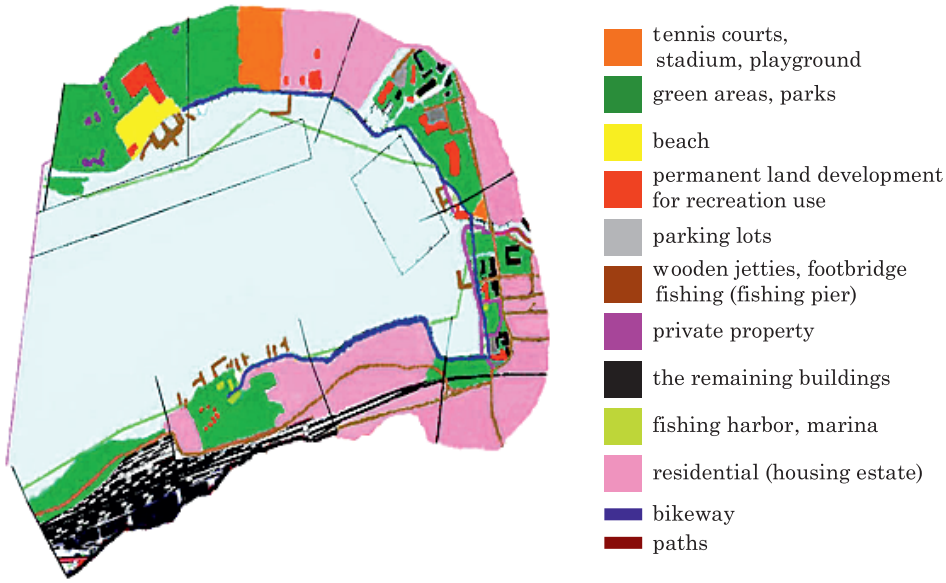

Fig. 3. The forms of development of tourist and recreational in the shoreline zone of Drwęckie Lake in the town limits of Ostróda

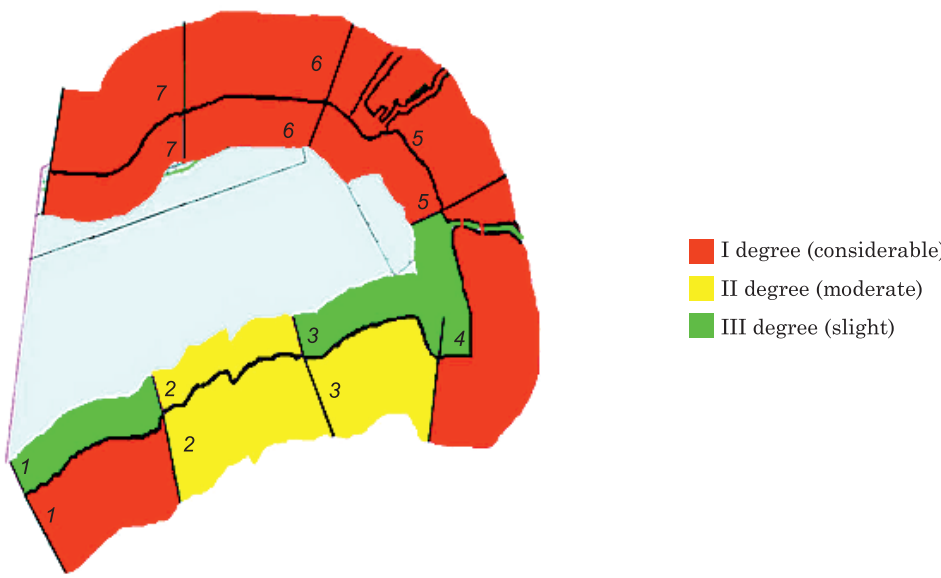

Fig. 4. The degree of burden the shoreline of Drwęckie Lake caused by the land development for tourism and recreation

The second most heavily burdened field is the one designated number *5*, where the land shore zone *K* index was 1.06, which also corresponds to the natural environment burden class I (Table 2, Figure 4). There are four accommodation facilities in this field, including 3 exclusive hotels, and several other summer apartments. There is an amphitheatre next to a hotel, a hardened surface car park and a water equipment rental with changing rooms. The catering industry is represented by a tavern and hotel restaurants. The bicycle and foot path runs along the lake's shores. There are also some green areas. The water part of this field was assigned the environmental load index value of 1.43 (Table 3). The reason is the waterski lift with a jetty, which attracts high numbers of tourists in the summer season (Figure 3).

Other fields classified to the first class of environmental burden (land shore zone) are the ones numbered *1*, *4* and *7* (Table 2, Figure 4). Field *1* is dominated by woods and green areas (Figure 3). Field *4* contains such elements of permanent land development as a lodging object with a casino, cafes and restaurants, including one in the shape of a ship. There are also green areas, a playground for children and a bicycle and foot path. The water part of the field *4* is occupies by the pier, which puts the field into class III of environmental burden (slightly loaded) – Table 3, Figure 4. Field *7* has such elements of land development as the recently opened Plaza Hotel with an unguarded beach and a water equipment rental, and a private residence. The water part of the field has been assigned a distinctly high value of the *K* index, i.e. 1.44 (considerable load), due to the presence of a jetty and part of the canoe track (Table 3, Figure 3).

The remaining fields *2* and *3* belong to class II land zone burden (moderate load) (Table 2, Figure 4). Except for a marina and a water equipment rental, the land parts of these fields do not comprise any significant tourist industry amenities. There is a cycle and foot path, same as in the other fields of the lake's shoreline. The water part of field *2* contains 9 small wooden jetties (Figure 3), which also corresponds to class II (Table 3, Figure 4).

The index *K* for the land shore zone did not reach, in any of the fields, such values that would classify the fields into class III of environmental load due to excessively intensive land development for tourism and recreational purposes (Table 2). Only fields *1*, *3* and *4* in water part, where there were just small jetties (Figure 3), had the *K* index values of less than 0.01 (Table 3) and were classified as belonging to class III (slight load) – Figure 4.

Due to the high *K* index values representing the environmental burden caused the land development for tourism and recreation (Table 4), both the land and water shore zones belong to class I of the environmental burden.

Table 4
Degree of land and water shore zone burden (K) of Drwęckie Lake, and their class burden (K_1)

Specification	K shore burden index	K_1 class burden index
Degree of land shore zone burden	0.52	I
Degree of water shore zone burden	0.47	I

Discussion

A degree of the transformation of nature by tourism depends on the character and form of tourism (PUCZKÓ and RÁTZ 2000), level of tourism industry development, planning and development of suitable infrastructure (POMUCZ and CSETE 2015), organization and management of tourist traffic, ecological awareness of tourists and the resistance of the natural environment to man-made pressure (MIKA 2000, BRAMWELL and POMFRET 2007).

A more intensive tourist flow often produced negative influences on the natural environment (KRUKOWSKA and ŚWIECA 2012). The most common adverse consequences are worse contamination of waters, air and soil, degradation of the landscape, interference with the biological balance, the littering of beaches and forests, and a higher level of noise (SIKORSKA-WOLAK 2004). When lakes are used for recreational purposes, the shoreline zones of water bodies are exposed to the most severe environmental risk (FURGAŁA-SELEZNIOW et al. 2011). The underlying cause of degradation is the intensive development of infrastructure for tourists and holidaymakers. This attracts more visitors, including those who come to beaches for sunbathing and swimming, to attend cultural and sports events, to ride motorboats or go on cruise ships, etc. (DEJA 2001, KURLETO 2014).

Drwęckie Lake is popular with many tourists for a number of reasons. First, it is located centrally in a town and therefore it is easily accessible. Second, the areas along the lake's shores offer many places to stay overnight (hotels, summer apartments, etc.) and to eat (restaurants, cafes). There is also well-developed infrastructure for water sports and excellent facilities for holding mass events. The lake attracts crowds of tourists and town residents in the summer season (STASIAK and WŁODARCZYK 2003, DÁVID et al. 2007, VASVÁRI et al. 2015).

Our research has demonstrated that both land and water shore zones around Drwęckie Lake are heavily burdened by various forms of land development for tourism and recreation. Among the seven distinguished fields, as many as five in the land zone, are considerably loaded while the remaining two are submitted to moderate burden. In the water part of the shore zone, 3 out of 7 fields have been determined to be considerably loaded, 1 field is distinguished by moderate burden and 3 other fields belong to class

III (slightly loaded). This confirms that the growth of infrastructure and increasing tourist attractiveness can exert strong pressure on the natural environment (PUCZKÓ and RÁTZ 2000, FURGAŁA-SELEZNIOW et al. 2010, KRUKOWSKA and KRUKOWSKI 2013).

Strong man-made pressure applied to waters and shores of Drwęckie Lake is created by mass events. Crowds of people are drawn to the lake by numerous attractions such as water sports shows and competitions. Consequently, all the factors mentioned by SKŁODOWSKI (2009) can produce adverse influences on the transformations occurring in the natural surroundings and waters of Drwęckie Lake.

Factors that affect negatively the natural environment, when accumulated intensively over a relatively small area, become an obvious threat to nature. Moreover, they can also threaten any further growth of tourism and recreation in this location because of the unwanted transformation of the surroundings or deteriorated water quality (HALL and HARKÖNEN 2006, PANTELIĆ et al. 2012, LOPES et al. 2016).

Our investigations have revealed certain threats to the shoreline area of Drwęckie Lake within the town limits due to the more and more intensive land development for tourism and recreation. Meanwhile, it should be emphasized that this is the most important water body that contributes to the development of tourism and recreation in the administrative district of Ostróda (NAWROCKA 2011, STASIAK and ROCHMIŃSKA 2011, SZWACKA-MOKRZYCKA 2012.). Hence, it is necessary to observe interactions between the growth of the tourism industry and the state of the natural environment (REMENYIK et al. 2013, POMUCZ and CSETE 2015). It is advisable to foresee whether the consequences of the lake's degradation will force the municipal authorities to undertake, some time in the future, costly efforts to reverse the trend and restore the lake (ŁOPATA 2013).

Conclusions

In this article, we draw attention to the importance of skilful spatial management within the lake's direct catchment. Another important point to make is that lake protection efforts should involve such actions that prevent excessive growth of infrastructure addressed to tourists. Denaturalization of the environment within the shore zone of a lake may lead to its future exclusion from use as a tourist destination due to unacceptable water quality. Hence, constant monitoring of environmental consequences brought about by the tourism industry is in order.

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TOMATO FIBRE AS POTENTIAL FUNCTIONAL FOOD INGREDIENTS

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K e y w o r d s: tomato pomace, bioactive substances, functional element.

A b s t r a c t

Vegetables are a very important element of the human diet due to the fact that they are carriers of many bioactive substances. Tomatoes are among them as a valuable source of dietary fibre, antioxidants (carotenoids, flavonols, vitamin C, tocopherol). Unused tomato waste resulting from the production of juice and paste can be used for making functional foods.

The aim of the research was to characterise tomato fibre as a carrier of bioactive substances and assess its usefulness as a functional component of foodstuffs.

Our research results showed that tomato pomace is a rich source of dietary fibre and in particular of its active fractions. However, the expected amounts of carotenoids including lycopene were not found out in them. Still it reveals an ability to bind metal cations. The tomato preparation can be regarded as a potential functional food additive.

MŁÓTO POMIDOROWE JAKO POTENCJALNY FUNKCJONALNY SKŁADNIK ŻYWNOŚCI

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S ł o w a k l u c z o w e: młóto pomidorowe, substancje bioaktywne, składnik funkcjonalny.

A b s t r a k t

Warzywa są bardzo ważnymi elementami pożywienia człowieka jako nośniki wielu substancji bioaktywnych. Do nich zaliczane są też pomidory jako cenne źródło błonnika pokarmowego, antyoksydantów (karotenoidów, flawonoli, witaminy C, tokoferolu). W tworzeniu żywności funkcjonalnej mogą być wykorzystane powstałe z produkcji soków i przecierów niezagospodarowane odpady pomidorowe.

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Celem badań była charakterystyka młóta pomidorowego jako nośnika substancji bioaktywnych i ocena jego użyteczności jako składnika funkcjonalnego żywności.

Wykazano, że młóto pomidorowe jest bogatym źródłem błonnika pokarmowego, w tym w szczególności jego aktywnych frakcji. Nie stwierdzono w nim natomiast spodziewanej ilości karotenoidów, w tym likopenu. Wykazuje ono zdolność do wiązania kationów metali. Preparat pomidorowy może być uznany jako potencjalny funkcjonalny dodatek do żywności.

Introduction

Vegetables as carriers of numerous bioactive substances are very important components of the human diet. Tomatoes are among the most popular vegetables in our country. They are a rich source of antioxidants (carotenoids, flavonols, vitamin C and tocopherol) and potassium. What is more, they contain very valuable from a nutritional point of view components such as: vitamins D, K and from the B group as well as dietary fibre (BOROWIAK 2007, FANASCA et al. 2006).

As a source of antioxidants tomatoes are first and foremost associated with the presence of carotenoids. Carotenoids are a group of bioactive compounds which in plants fulfil a protective role and the main pigment in tomatoes – lycopene – is responsible for the characteristic red colour of the fruit. In ripe tomatoes lycopene makes 80–90% of all caretonoids.

Dietary fibre is a natural component of plants; it is a mixture of compounds resistant to the activity of digestive enzymes in the human digestive system. Admittedly, dietary fibre has no nutritional value but is indispensable in a diet as it fulfils other pro-health functions. Soluble fibre has the ability to reduce the levels of LDL cholesterol and at the same time improves proportions between the desirable HDL and undesirable LDL fractions, and slows down the hydrolysis and absorption of nutritional components. The insoluble fibre fraction stimulates peristalsis and accelerates the flow of intestinal contents. The ability to bind heavy metals is a particular advantage of dietary fibre (BARTNIKOWSKA 1995, BORYCKA 2012, GÓRECKA 2004).

It is worth mentioning that a lot of research points to a correlation between consumption of tomatoes and their products and reduced risk of cancer diseases (BOURN and PRESCOTT 2002, SHI and LE MAGUER 2000).

In Poland tomatoes are a valuable raw-material used in the fruit and vegetable processing industry. Literature data (ZALEWSKA-KORONA and JABŁONSKA-RYŚ 2012) indicate that ca. 150 thousand tonnes of field-grown tomatoes, i.e. ca. 50% of entire crops, are processed annually, mainly into a tomato concentrate and to a lesser degree into juices, ketch-up and other sauces; in smaller amounts – into canned tomatoes and as additives to meat, fish and vegetable products. A post-production waste in these processes is tomato pomace.

On the one hand, worldwide trends in waste management aim at converting as much waste as possible into useful products; on the other hand, investigations are carried out into the ways of minimising the risk for the natural environment not only by eliminating waste but also by converting it into useful components (OKONKO et al. 2008). The most popular way of fruit and vegetable waste management, including pomace management, is using it for fodder due to the high contents of such components as: organic acids, nitrogen-free compounds, saccharides, fatty substances and vitamins. The result is reducing the costs of feeding animals (ŚWIĄTKIEWICZ and KORELESKI 2003, TARKO et al. 2012). Fruit and vegetable pomace, when used for the production of ethanol, can become an important source for biofuel. Fermentation of saccharides into alcohol is perceived as one of the best methods to get out the cumulative energy from the biomass (CHATANTA et al. 2008). Fruit and vegetable waste is also a rich source of dietary fibre. What is more, the colour fruit and vegetable waste can be a source of natural, biologically active pigments (and tomato pomace is a carotenoid carrier).

Tomato pomace is also used in beauty and food sectors. It is worth mentioning that in 2011 J. Bajerska from Poznan University of Technology prepared special rye bread on the basis of the tomato pomace enriched leavening. The product was a finalist of the 2011 Poznan Invention Competition (*Portal innowacji*. 2013). It was the inventor's intention to make the product counteract obesity and factors contributing to the development of sclerosis and diabetes and at the same time be tasty. However, a considerable part of this valuable raw material goes to rubbish dumps.

The aim of our investigations was to characterise tomato pomace as a bioactive substance carrier and to assess its usefulness as a functional component of foodstuffs.

Materials and Methods

In our work we used tomato pomace obtained during the tomato concentrate production in the Fruit and Vegetable Processing Industry Plant (ZPOW) in Milejów.

In the organoleptic analysis we used canned pâtés which are commonly available on the domestic market: Mazowiecki pâté – PM and poultry pâté – PD.

In the investigated preparations we determined the TDF (total dietary fibre) content by means of the AOAC method (PROSKY et al 1984) in the course of which the ash content was determined and the Kjeldahl method was used to determine the amount of protein. To determine the complete chemical compo-

sition of fibre preparations, the fat content was determined in the ether extract using the Soxhlet method as it is recommended by Polish standards (KUŁAS-KREŁOWSKA 1993). Moreover, the saccharide content in the fibre samples was determined according to the AOAC reference procedures (AOAC 1990). Soluble and insoluble parts of dietary fibre were determined by the Aspa method (Asp 1983).

In the investigated preparations dietary fibre fractions (cellulose, hemicellulose, lignin) were determined by the detergent method according to Van Soest, and McQueen and Nicholson (VAN SOEST and MCQUEEN 1973, MCQUEEN and NICHOLSON 1979).

Total pectin fractions were isolated in high temperatures with the use of 0.5 M HCl according to the procedure developed by KING (1987) whereas the water soluble fraction was isolated by Kawabata's extraction method (KAWABATA 1997). To determine the uronic acid contents in extracts we used Bitter's borate-based spectrophotometric method (KŁYSZEJKO-STEFANOWICZ 1972).

The cation-exchange capacity was determined on the basis of MCCONNELL'S procedure (MCCONNEL et al. 1974).

Mineral characteristics of pomace preparations included dry mineralization of samples and atomic absorption spectrometry (AAS) (KUŁAS-KREŁOWSKA 1993). To determine cadmium and lead contents we used the flameless method with use of the graphite cuvette.

In all investigations the average of was calculated from 9 measurements.

The sensory evaluation based on a 5-point scale reference card for meat pâtés (PIECZONKA 1995) was carried out by a panel of 11 persons of verified sensory sensitivity and meeting the requirements of the PN-ISO standards (8586-1:1996, 8586-2:1996, 6658:1998). They evaluated: general appearance and colour, texture, taste and flavour of meat pâtés with and without additives. The following importance coefficients (determined by the experts' estimation method) were attributed to particular product characteristics: 0.15 – to appearance and colour, 0.25 – to texture and 0.60 – to taste and flavour. Using the importance of particular characteristics, the sensory evaluation of total quality was calculated.

By comparing two independent samples and two dependent samples (Student's t-test) (DOBOSZ 2001), it was analysed whether the tomato pomace additive to a pâté had any impact on the sensory quality of the final product.

Results and Discussion

The investigated preparation was characterised by an orange red colour. The examined tomato waste contained ca. 12% of fat, significant amounts of proteins (ca. 21%) and small amounts of total saccharides (ca. 8.5%) – Table 1.

The research by Del Valle and co-workers (DEL VALLE et al. 2006) confirms the above contents of proteins (ca. 19%), although indicates lower by half levels of fat (ca. 6%) and higher contents of total saccharides (ca. 26%).

Table 1

Chemical characteristics of tomato pomace (on a dry matter basis (DMB))

Components	Parameter	$\bar{x} \pm S_x$
Protein	$n \cdot 6.25$ [%]	21.06 ± 0.92
Fat	[%]	13.92 ± 1.19
Saccharide content	total saccharides content [%]	8.42 ± 0.08
	saccharose content [%]	0.11 ± 0.01
Bioactive components	carotenoid content [mg/100 g]	1.52 ± 0.03
	lycopene content [mg/100 g]	0.004 ± 0.001

The differences in determinations can be caused by different varieties of the raw-materials used in processing, the country of origin and applied research methodology. On the other hand, PACHOŁEK (2010) determined a similar protein content in tomato pomace (ca. 24%) and considerably higher in tomato seeds (ca. 33%), and higher, almost twice as high, fat content (in pomace and seeds – ca. 21% and 22.5%, respectively).

Carotenoids can be a particularly important bioactive component of tomatoes and tomato waste. Research work reveals that they can reduce or stop negative changes in foods (CLINTON 1998, HARMUŁKA and WAWRZYNIAK 2004). Lycopene and β-carotene are among basic carotenoids appearing in tomato fruits. The composition and content of carotenoids in tomatoes, and in particular of lycopene, depend to a large extent on the fruit variety and its ripeness. According to Sadler (SADLER et al. 1990) the average lycopene content in field-grown tomato varieties can range between 4.0 to 11.0 mg/100 g, whereas Harmułka and Wawrzyniak (2004) speak about the levels of 0.9 ÷ 7.74 mg/100 g of fresh mass, depending on the fruit variety and ripeness.

The investigated tomato waste proved to be a rather poor source of carotenoids, the content of which was determined at the level of 1.5 mg/100 g, including only 0.004 mg/100 g of lycopene. In the available literature on the topic no information was found concerning the morphological structure of the tomato and the location of carotenoid (including lycopene) particles in it, therefore we can only make conjectures about the causes of this phenomenon. Literature sources claim (HARMUŁKA and WAWRZYNIAK 2004) that carotenoids are very sensitive to oxygen, especially in high temperatures. It is worth mentioning that after the raw-materials have been processed, carotenoids including lycopene, are more easily accessible owing to a larger surface of the processed products. Moreover, their chemical structure changes under

the influence of temperature and they enter the processed products more easily (HARMUŁKA and WAWRZYNIAK 2004). Thus it can be assumed that very few of them remain in the pomace after the carotenoid rich paste has been obtained.

The research results for tomato waste dietary fibre and its fractional composition included in Table 2 show that it is a valuable source of fibre as it contains 52% ÷ 54% of total dietary fibre (TDF). It is worth mentioning that this level is stable despite the application of different methods of its determination. The research results compared with literature data regarding other vegetable waste also prove that the tomato preparation is characterised by a high TDF level, in many cases much higher than that for other vegetable waste. In their research Del Valle and co-workers (DEL VALLE et al. 2006) obtained similar results for TDF contents (ca. 59%). The literature on the subject gives different TDF values for other vegetable pomace; for example in carrot pomace BORYCKA and GÓRECKA (2005) found ca. 65% of TDF, whereas in sugar beet pomace Tarko and co-workers (2012) determined only ca. 13% of total dietary fibre.

Table 2

Dietary fibre content in tomato pomace (on a dry matter basis (DMB))

Components		Parameter [%]	$\bar{x} \pm S_x$
Dietary fibre	total	TDF	52.60 ± 0.77
	–	insoluble	50.13 ± 2.76
		soluble	4.29 ± 0.40
		NDF	48.42 ± 0.44
		cellulose	15.15 ± 0.34
		hemicellulose	10.80 ± 0.53
		lignin	22.76 ± 0.36
		total pectins	4.48 ± 0.14
		water soluble pectins	0.12 ± 0.03

The investigated tomato pomace contains over 48% of detergent dietary fibre (NDF), which in comparison to other vegetable waste is a significantly high value (Table 2). For example: literature sources (BORYCKA and GÓRECKA 2005) quote its content in carrot pomace as NDF < 35%. It is worth noticing that research results obtained by NAWIRSKA and UKLAŃSKA (2008) also point to a significant effect of the carrot variety on the fractional fibre content in pomace. Apparently the difference can reach as much as ca. 10% NDF. On the other hand Schmidt and co-workers (1999) determined the NDF content in tomato from the *Cucurbitaceae* family to be at a low level of ca. 15%.

The presence of fractions containing reactive functional groups, i.e. lignin, hemicellulose and pectins accounts for the dietary fibre functionality. Thus, thinking about the pomace as a potential functional food additive the relatively high contents of lignin and hemicellulose in comparison to other vegetable waste (among others, carrot pomace) must be emphasised (BORYCKA and GÓRECKA 2005, NAWIRSKA and UKLAŃSKA 2008). Apart from this, tomato pomace is a rather poor (ca. 5%) source of pectins in comparison to, for example, carrot pomace (ca. 8%) (BORYCKA and GÓRECKA 2005, NAWIRSKA and UKLAŃSKA 2008). In comparison to fruit pomace it is characterised by significantly higher contents of lignin and hemicellulose fractions, but a lower content of pectins (BORYCKA 2000, 2012). The function of the above mentioned presence of fibre fractions and at the same time an indicator of the ability to bind, among others, metals including heavy metals, is the determined CEC – i.e. ability to bind sodium ions (BORYCKA 2012).

Literature data indicate that ion-exchange resin capacity is related to the number of ions which can be exchanged per unit mass of ion-exchange resin and is defined in equivalents or millequivalents per a gram of the ion-exchanger. McConnell and co-workers (MCCONNEL et al. 1974) proved that a significant number of fibre varieties behave like a monofunctional resin poorly exchanging a cation. However, it must be mentioned that fruits were characterised by higher CEC capacity than vegetables (e.g. apples – 1.9 mE/g, oranges – 2.4 mE/g, whereas carrots – 0.15 mE/g, and potatoes – 0.04 mE/g) (GÓRECKA 2004).

In the case of tomato waste CEC was determined at the level close to that of currant pomace and slightly lower than in apple-currant pomace preparations of the same weight (0.26 mEq/1 g and 0.30 mEq/1 g, respectively) (BORYCKA 2000). It must be mentioned that both compared pomace preparations turned out to be good sorbents for heavy metals, which lets us expect a metal sorption ability in the case of tomato preparations (GÓRECKA 2004).

CASTERLINE and KU's thesis (1993) that the presence of metals in the environment can affect properties of acidic polysaccharides due to the creation of insoluble metal-polysaccharide complexes is also worth remembering.

Research results included in Table 3 let us qualify tomato waste preparations as potential food additives because the levels of heavy metals contained in them do not exceed the permitted level defined in the Minister of Health's Regulation concerning acceptable safe limits for chemical and biological contaminations in foodstuffs (Rozporządzenie... Dz.U. nr 37. poz. 326.).

To check the effect of a tomato additive on the sensory quality of selected food products, a sensory analysis (5-point scale) of meat products enriched by the investigated preparation was carried out (Table 4).

Table 3

Contents of selected metals in the tomato fibre preparation

Quantity	CEC mE/g	Metal levels [μg/g ± SD]	
		Cd	Pb
Content	0.22 ± 0.02	0.038 ± 0.005	0.25 ± 0.09

Table 4

Sensory analysis results for pâtés with the tomato pomace preparation additive

Product		Additive [%]	Statistical measures	
			$\bar{x}$	S_x
Pâté	Poultry	0	4.13	0.47
		1	4.11	0.53
	Mazowiecki	0	4.54	0.53
		1	4.59	0.36

Table 5

Effect if the tomato pomace additive on the sensory quality of pâtés – results of Student's *t*-test

Products compared		"t-value"
Poultry pâté PD-0	PD-BPOM	0.102
Mazowiecki pâté PM-0	PM-BPOM	0.375

The asterisk (*) means that the *F*-test value allows us to reject the null hypothesis (at the level $\alpha = 0.05$)

The arithmetic mean values of the evaluation on a 5-point scale imply that a 1% addition of tomato pomace affected the sensory quality of the final product, which was later verified by the Student's t-test. This led to a thesis that a tomato fibre additive to a pâté affects the sensory quality level of the final product.

The statistical analysis results showed that a 1% additive of tomato pomace to examined pâtés does not significantly affect their sensory quality.

Conclusions

1. The investigated tomato pomace fibre preparation was characterised by a high (ca. 50%) content of dietary fibre.

2. The preparation distinguished itself among other waste fruit sources by higher levels of lignin and hemicellulose active in metal exchange reactions.

3. Results of CEC tests indicate that the ability of the pomace preparation to bind cations is relatively high in comparison to other waste fruit sources.

4. The tomato preparation can be considered a potential functional food additive.

5. Our examinations proved that the tomato pomace preparation can be an attractive fibre additive to the pâtés – Mazowiecki and poultry ones – as 1% of this additive does not have a significant effect on their sensory quality.

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ANALYSIS OF THE IMPACT OF CLIMATE FACTORS ON THE LEVEL OF MECHANICAL PARAMETERS OF SELECTED PACKAGING FILMS USED FOR FOOD PRODUCTS

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K e y w o r d s: climate factors, functional value of packaging films, food product packaging.

A b s t r a c t

Plastic films are of key importance as a group of materials used for packaging food products. It is therefore crucial that they meet specific functional and durability requirements as well as comply with all regulations regarding food contact materials. A degree to which a set of properties of these materials satisfies the requirements connected with their usage determines their functional value. The level of functional value depends to a large extent on climate factors affecting these materials in the post-production stage.

The aim of this work was to analyze the effect of climate factors on the level of changes of the parameters characterizing the functional value of polyolefin packaging films used for food products.

The research was conducted with the main focus on the scope and intensity of changes of selected properties of packaging films in different microclimate conditions. The results became the basis of assessing the impact of climate factors on the level of changes of the parameters characterizing functional value and served as a groundwork to the analysis of the correlation between the changes in the parameters and the level of functional value of the plastic films.

ANALIZA WPŁYWU CZYNNIKÓW KLIMATYCZNYCH NA POZIOM ZMIAN PARAMETRÓW CHARAKTERYZUJĄCYCH WARTOŚĆ UŻYTKOWĄ FOLII OPAKOWANIOWYCH Z TWORZYW SZTUCZNYCH PRZEZNACZONYCH DO PAKOWANIA PRODUKTÓW SPOŻYWCZYCH

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S ł o w a k l u c z o w e: czynniki klimatyczne, wartość użytkowa folii opakowaniowych, pakowanie produktów spożywczych.

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A b s t r a k t

Folie z tworzyw sztucznych stanowią ważną grupę materiałów wykorzystywanych w opakowalnictwie do pakowania m.in. produktów spożywczych. W związku z czym muszą spełniać określone wymagania wytrzymałościowe oraz wymagania stawiane materiałom przeznaczonym do kontaktu z żywnością. Stopień spełnienia przez materiały stawianych im wymagań z punktu widzenia ich przeznaczenia wyznacza ich wartość użytkową. Poziom wartości użytkowej folii jest zdeterminowany w dużym stopniu wpływem czynników klimatycznych, które oddziałują na te materiały w sferze poprodukcyjnej.

Celem pracy jest analiza wpływu czynników klimatycznych na poziom zmian parametrów charakteryzujących wartość użytkową folii opakowaniowych z tworzyw sztucznych przeznaczonych do pakowania produktów spożywczych.

Introduction

Plastic films belong to one of the most important groups of materials used for packaging. Polyolefin films dominate in this group with the market share of 90%. This kind of films is widely used in several different industries with a particular emphasis on food production performed with the use of filling and packaging machines. Because of that, polyolefin films have to meet specific functional and durability requirements as well as comply with all regulations regarding food contact materials (LISIŃSKA-KUŚNIERZ and KAWECKA 2012, LISIŃSKA-KUŚNIERZ and CHOLEWA-WÓJCIK 2012). A degree to which a set of properties of these materials satisfies the requirements connected with their usage determines their functional value. A required level of the packaging film's functional value can be achieved by a proper selection of production methods, extrusion parameters as well as the raw materials used. However, all the activities leading to attaining that level cannot merely focus on the production stage. Packaging films are subject to aging processes as a result of which irreversible changes in their properties take place, which in turn affects the overall functional value of the films. The level of functional value depends to a large extent on climate factors affecting these materials in the post-production stage. That is why, in order to create a stable level of functional value of packaging films it is important to ensure proper storage conditions of the films before the packaging processes take place, and then of the food products packed in them (CHOLEWA-WÓJCIK 2011). The aim of this work was to analyze the effect of climate factors on the level of changes of the parameters characterizing the functional value of polyolefin packaging films used for food products.

Materials and Methods

The empirical studies focused on polyolefin films manufactured in Poland. Five different types of films were selected, among which homogenous films as well as the ones produced from two kinds of polyolefin and those with extra minerals added, such as chalk or talc, could be found. Generic presentation of research material is shown in Table 1.

Table 1

Presentation of research material

Type of polyolefin film	Trade name	Producer
Multilayer film OPP	Bifol BG	Flexpol
Coextruded laminate OPP-PE	Biaxfol	Folmar
Multilayer film PE (LLDPE)	Politerm TB	TB Opakowania
Multilayer film PE+PP	Cristel	Plasticos
Multilayer film with minerals	Ecor FPO WRAP	Ecor

The destructive impact of the temperature, solar radiation and relative humidity on polyolefin films was analyzed in several microclimate condition variants. The films were stored for a period of 12 months.

Variant I – stable microclimate conditions with the following parameters: $T = 20\pm1^{o}C$, RH = 65±2% (normal atmospheric research conditions according to EN-ISO 554:1996).

Variant II – stable microclimate conditions with the following parameters: $T = 40\pm1^{o}C$, RH = 65±2% (the temperature is 20°C higher in relation to the normal conditions with the relative air humidity as given above).

Variant II bis – stable microclimate conditions with the following parameters: $T = 40\pm1^{o}C$, RH = 65±2% with optional xenon lamp irradiation at a dose of 50 MJ m^{-2}.

Variant III – stable microclimate conditions with the following parameters: $T = 20\pm1^{o}C$, RH = 90±2% (the temperature on a normal conditions level with the relative air humidity on a dramatically high level).

Variant IV – stable microclimate conditions with the following parameters:

$T = -20\pm1^{o}C$, RH = 40±2% (the conditions include the usage of films for packing deep-frozen products).

Variant V – changeable microclimate conditions with the following parameters $10\pm1^{o}C < T < 22\pm1^{o}C$ and 56±2% < RH < 64±2% (monitored in the warehouse of the packaging film manufacturer without the possibility of regulating the conditions of the surrounding environment.

Empirical research program to assess the impact of climatic factors on changes in the value in use of polyolefin packaging film during aging are shown in Table 2.

Table 2
Empirical research program to assess the impact of climatic factors on the value in use of packaging film

Microclimate parameter affectingon film properties	Microclimate condition variant	Test cycle (month)	Research time (month)
Tempeture (T) T = 20°C, 40°C and RH = 65% T = -20°C and RH= 40%	I, II, IV	1	12
		4	
UV radiation and temperature (T) T = 40°C I RH= 65%	II BIS	–	0,25–1*
Humidity (RH) RH = 65% and 90% and T = 20°C	I, III	1	12
Temperature and humidity fluctuations 10±1°C < T < 2 2±1°C 56±2% < RH < 64±2%	V	1	

Results and Discussion

In order to verify the hypothesis of the materiality of the impact of climate factors (temperature, humidity and UV radiation) on changes in mechanical parameters affecting the polyolefin films' functional value, a one-factor analysis of variance was performed with the use of ANOVA. The basis of this analysis was formed by the values of parameters of break load and elongation of all tested films, previously stored in different variants (I–V) of microclimate conditions at different temperature and humidity levels as well as with a xenon lamp irradiation option (variant II bis). Two research hypotheses were formed for the sake of the analysis. According to the null hypothesis, microclimate conditions do not differentiate the average levels of value of analyzed parameter. The alternative hypothesis suggests that there are vital differences between average values of parameters depending on different microclimate conditions. In order to accept or reject the zero hypothesis, an F-statistics method (or F-test) was used. If the final value of F-statistics calculated based on the tests will fall within the critical set, the tested hypothesis has to be rejected and the alternative one accepted. If, however, the value of F-statistics will be outside the critical set, there is no reason to reject the null hypothesis. The level of significance was set on $\alpha = 0{,}05$ (the probability of rejecting the null hypothesis). Selected results of the analysis of the impact of climatic factors on the level of changes of parameters affecting the plastic films' functional value are presented in Table 3.

The one-factor variance analysis revealed a relevant impact of microclimate conditions on the level of parameters characterizing functional value of all tested polyolefin films. The probability test was lower than 0.05 in all plastic

Table 3

Selected results of the analysis of the impact of climate factors on the level of changes of parameters affecting the plastic films' functional value after 12 months of storage

Plastic film type	Parameter	Direction	Average value						F Statistics	Value p
			microclimate condition variant							
			I	II	III	IV	V	II BIS		
Biaxfol	break load P (N)	along	20.494	17.599	20.365	22.017	20.406	4.502	105.636	0.000
	elongation W (%)		32.161	29.951	32.067	38.071	32.118	5.143	77.645	0.000
	break load P (N)	across	21.937	20.074	21.751	23.518	21.629	x	46.631	0.000
	elongation W (%)		24.515	21.061	24.594	27.794	23.902	x	60.259	0.000
Cristel	break load P (N)	along	18.591	17.634	18.426	19.095	18.513	0.308	11.248	0.000
	elongation W (%)		47.676	46.706	48.029	51.409	48.445	8.588	16.504	0.0 00
	break load P (N)	across	20.718	18.272	20.622	21.556	20.592	x	48.144	0.000
	elongation W (%)		41.136	40.095	40.951	42.391	40.947	x	13.062	0.000
BG	break load P (N)	along	29.463	27.222	28.935	20.656	29.366	0.453	220.911	0.000
	elongation W [%]		48.650	42.912	47.742	37.081	47.729	3.773	84.472	0.000
	break load P (N)	across	50.001	41.941	49.297	23.746	49.886	x	495.887	0.000
	elongation W [%]		11.908	8.863	10.798	35.299	11.478	x	240.489	0.000
TB	break load P (N)	along	19.732	17.145	19.592	20.656	19.689	4.031	69.368	0.000
	elongation W [%]		39.360	34.578	38.855	37.081	39.030	4.897	8.131	0.000
	break load P (N)	across	21.121	19.689	20.502	23.746	21.049	x	148.501	0.000
	elongation W [%]		36.410	33.695	35.512	35.299	35.683	x	14.385	0.000
Ecor	break load P (N)	along	13.717	12.812	12.960	19.095	13.118	3.361	700.133	0.000
	elongation W [%]		443.113	120.066	205.189	51.409	453.238	7.076	1.564	0.182
	break load P (N)	across	22.986	22.216	22.848	21.556	23.103	x	36.649	0.000
	elongation W [%]		108.280	99.257	113.242	42.391	113.940	x	327.647	0.000

x – no results for different variants of microclimate conditions, resulting from the research program

films that were analyzed. The only exception there was ECOR plastic film; the variance analysis of elongation along the length did not reveal any substantial differences in connection with storage conditions variant. The results of the analysis show a significant statistical difference between the values obtained in various variants of microclimate conditions. The impact of different microclimate conditions on the scope of changes in break load (P) and elongation (W) during storage in time period t = 12 months in different climate variants is presented in Figures 1–2.

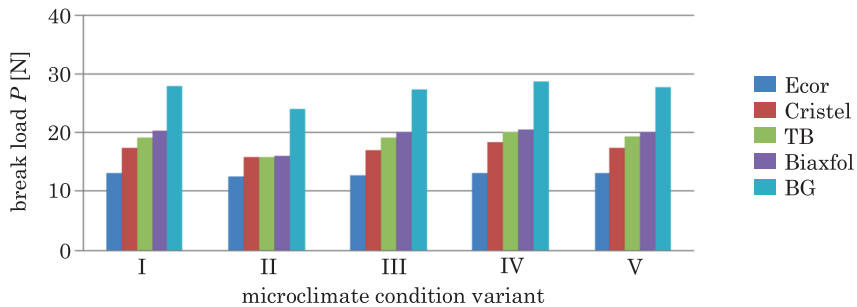

Fig. 1. The impact of different microclimate conditions on the scope of changes in break load (P) during storage in time period t = 12 months in different climate variants

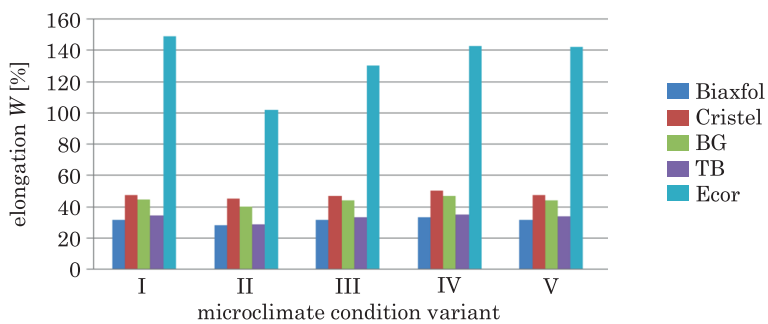

Fig. 2. The impact of different microclimate conditions on the scope of changes in elongation (W) during storage in time period t = 12 months in different climate variants

Based on the analysis of the impact of different microclimate conditions on the scope of changes in mechanical properties during storage it can be said that both the scope and dynamics of changes are much greater in case of elongation than in case of break load. This, of course, means that elongation is a parameter strongly responsive to the processes of thermal degradation.

Due to the fact that the variance analysis showed significant differences in values of mechanical parameters of the plastic films stored in five microclimate

variants, it was necessary to use post hoc tests. Further analysis was performed with the application of Tukey's HSD test (Honestly Significant Difference test) with the aim to point out the most significant differences in average values of mechanical parameters. The results of the HSD test enabled us to determine the microclimate condition variant pairs which do not much modify the parameters characterizing mechanical properties. The obtained results are presented in Table 4.

Table 4

Tukey's HSD test results

Film's parameter	Direction	Plastic film type				
		Biaxfol	Cristel	BG	TB	Ecor
Break load *(P)*	along	I–III I–V	I–III I–V III–V	I–III I–V III–V	I–III I–V III–V	II–III II–V III–V
	across	I–III I–V	I–III I–V	I–V	I–V	I–III I–V III–V
Elongation *(W)*	along	I–III I–V III–V	I–III I–V III–V II–III	I–III I–V III–V	I–III I–IV I–V	
	across	I–III I–V III–V	I–III I–V III–V II–V	I–III I–V III–V	I–III I–V III–V	I–III I–V III–V

I, II etc. – microclimate condition variants

The analysis of obtained results, which are consistent with the research carried out by Bielinski, Schael, Serge, Laurent among others, became the basis of the evaluation of the impact of analyzed parameters on the level of changes in functional properties of polyolefin films (BIELIŃSKI 2006, SCHAEL 2003, SERGE and LAURENT 2002).

The rates of dynamics of degradation presented in Tables 5–6 and a calculated average period of the speed of changes in the long-term storage in two microclimate conditions variants became the basis of one-factor variance analysis. The aim of this analysis was to verify the hypothesis on the possibility of determining the critical boundary property[1]. In the variance analysis two hypotheses were formed. According to null hypothesis, the parameters characterizing mechanical properties and structural changes do not present any significant changes in average-term values during long-term storage. The alternative hypothesis is based on the assumption that there are significant

[1] Critical boundary property is a property in the set of critical characteristics which is the first to cease to meet the requirements related to functional value (PN-ISO 6707-1:2008).

changes in dynamics between analyzed parameters that have an impact on the average-term speed of changes which can be determined by the critical boundary property. In order to decide which of the two hypotheses should be accepted, the method of *F*-statistics was used. If the value of *F*-statistics calculated based on the tests will fall within the critical set, the tested hypothesis has to be rejected and the alternative one accepted. If, however, the value of *F* statistics will be outside the critical set, there is no reason to reject the null hypothesis. The level of significance was set on $\alpha = 0.05$ (the probability of rejecting the null hypothesis).

Table 5

The rate of dynamics of changes of critical properties' parameters and the average-term speed of decline during long-term storage in microclimate conditions variant I [%]

Type of film	Parameter	Direction	Cycle of research (4 months)				Average-term speed of changes [%]
			0	4	8	12	
Biaxfol	break load *P*	along	100	99.3	99	98.4	-0.5
		across	100	101	95	94.1	-2.0
	elongation *W*	along	100	97.3	95	94.1	-2.0
		across	100	103	95	92.8	-2.5
	molecular weight		100	86.4	77	71.8	-10.5
Cristel	break load *P*	along	100	100	94	91.8	-2.8
		across	100	93.9	93	92.2	-2.7
	elongation *W*	along	100	102	101	99.9	0.0
		across	100	101	99	98.3	-0.6
	molecular weight		100	83.9	75	69.1	-11.6
BG	break load *P*	along	100	95.3	88	87.2	-4.5
		across	100	91.3	75	73.5	-9.8
	elongation *W*	along	100	87.9	79	78.8	-7.6
		across	100	89.1	69	68.4	-11.9
	molecular weight		100	94.4	57	33.3	-30.7
TB	break load *P*	along	100	98.5	96	95.6	-1.5
		across	100	93.9	93	92.5	-2.6
	elongation *W*	along	100	94.4	82	81.2	-6.7
		across	100	103	99	96.9	-1.0
	molecular weight		100	81.9	69	66.5	-12.7
Ecor	break load *P*	along	100	97.1	101	99.8	-0.1
		across	100	98.4	97	95.8	-1.4
	elongation *W*	along	100	103	80	56.9	-17.1
		across	100	93.3	72	70	-11.2
	molecular weight		100	92.9	78	73.3	-9.8

Table 6

The rate of dynamics of changes of critical properties' parameters and the average-term speed of decline during long-term storage in microclimate conditions variant II [%]

Type of film	Parameter	Direction	Cycle of research (4 months)				Average-term speed of changes [%]
			0	4	8	12	
Biaxfol	break load *P*	along	100	85.3	82	77.9	-8.0
		across	100	93.4	83	81.2	-6.7
	elongation *W*	along	100	90.4	87	83.8	-5.7
		across	100	84.9	79	76.9	-8.4
	molecular weight		100	82.7	73	67.1	-12.5
Cristel	break load *P*	along	100	96.3	89	83.2	-5.9
		across	100	83.4	78	77.2	-8.3
	elongation *W*	along	100	100	97	95.1	-1.7
		across	100	98.9	97	94.4	-1.9
	molecular weight		100	75.5	71	61.7	-14.9
BG	break load *P*	along	100	91.3	82	75.3	-9.0
		across	100	67.8	65	63.5	-14.0
	elongation *W*	along	100	72.1	71	70.3	-11.1
		across	100	70	46	44.3	-23.8
	molecular weight		100	71.6	30	22.8	-38.9
TB	break load *P*	along	100	85.2	79	79.1	-7.5
		across	100	88.4	86	83.2	-5.9
	elongation *W*	along	100	96.4	93	87.2	-4.5
		across	100	80.4	70	68.5	-11.8
	molecular weight		100	68.6	67	59.4	-15.9
Ecor	break load *P*	along	100	96.2	96	95.2	-1.6
		across	100	95.9	92	91.6	-2.9
	elongation *W*	along	100	49.6	41	38.9	-27.0
		across	100	86.3	65	60.4	-15.5
	molecular weight		100	89.1	77	68.8	-11.7

The analysis of obtained results allows to draw a conclusion that there are statistically significant differences in the dynamics of changes in tested parameters. Based on the interpretation of the intensity of changes of those parameters as well as the average-term speed of decline, a molecular weight was observed to be the critical parameter. This result is supported by the research results of several authors, such as DOBKOWSKI (2006), BUDTOV et al. (2003), SCARFATO et al. (2002). They believe that, the consequence of aging as a result of the mechanism of thermal or photo oxidation is the fact that the first changes appear in the structure of the polymers. The further effect of

Table 7
A correlation of the impact of molecular weight on the changes in mechanical properties of polyolefin films stored in microclimate conditions variant I and II

Type of film	Parametr	Direction	Regression model for variant I $\overline{M_w} = f(P)$; $\overline{M_w} = f(W)$	Regression model for variant II $\overline{M_w} = f(P)$; $\overline{M_w} = f(W)$
Biaxfol	break load P	along	$\overline{M_w}$ = 19,5217 + 0,004P	$\overline{M_w}$ = 6,7986 + 0,0468P
		across	$\overline{M_w}$ = 17,5959 + 0,0179P	$\overline{M_w}$ = 9,2356 + 0,0462P
	elongation W	along	$\overline{M_w}$ = 26,5353 + 0,0234W	$\overline{M_w}$ = 17,0416 + 0,0555W
		across	$\overline{M_w}$ = 18,7697 + 0,0242 W	$\overline{M_w}$ = 18,7697 + 0,0242W
Cristel	break load P	along	$\overline{M_w}$ = 14,0906 + 0,0151 P	$\overline{M_w}$ = 11,5764 + 0,022 P
		across	$\overline{M_w}$ = 16,1161 + 0,0163 P	$\overline{M_w}$ = 7,7787 + 0,0401P
	elongation W	along	$\overline{M_w}$ = 47,8923 – 0,0009W	$\overline{M_w}$ = 42,2957 + 0,0154W
		across	$\overline{M_w}$ = 6,8742+0,0623W	$\overline{M_w}$ = 39,0874 + 0,0059W
BG	break load P	along	$\overline{M_w}$ = 26,6571 + 0,0173P	$\overline{M_w}$ = 20,2426 + 0,0352P
		across	$\overline{M_w}$ = 39,5647 + 0,0705P	$\overline{M_w}$ = 28,6137 + 0,0757P
	elongation W	along	$\overline{M_w}$ = 40,6372 + 0,0508W	$\overline{M_w}$ = 32,6285 + 0,0559W
		across	$\overline{M_w}$ = 35,8417+0,0153W	$\overline{M_w}$ = 8,5586 + 0,0209W
TB	break load P	along	$\overline{M_w}$ = 17,6299 + 0,0062P	$\overline{M_w}$ = 20,2426 + 0,0352P
		across	$\overline{M_w}$ = 17,4018 + 0,0117P	$\overline{M_w}$ = 13,2864 + 0,022P
	elongation W	along	$\overline{M_w}$ = 18,0042 + 0,0592W	$\overline{M_w}$ = 12,7647 + 0,072W
		across	$\overline{M_w}$ =1,9576 + 0,0358W	$\overline{M_w}$ = 32,8187 + 0,0077W
Ecor	break load P	along	$\overline{M_w}$ = 13,7 – 0,0009P	$\overline{M_w}$ = 20,2426 + 0,0352P
		across	$\overline{M_w}$ = 20,3805 + 0,004P	$\overline{M_w}$ = 16,9309 + 0,0082P
	elongation W	along	$\overline{M_w}$ = -126,4102 + 0,503 W	$\overline{M_w}$ = -251,8698 + 0,5971W
		across	$\overline{M_w}$ = -46,8838 + 0,231W	$\overline{M_w}$ = -26,3672 + 0,2068W

structural changes in polymer's macromolecules is a break in the chain which leads to a decrease in molecular weight. That is why the molecular weight can be considered as a critical parameter and it can be thus concluded that the changes leading towards the loss in original functional properties of the product are initiated there. According to the research results of BIELIŃSKI (2006), even a small share of reactions connected with a decrease in molecular weight (chain break) leads to a deterioration in mechanical properties. Based on data presented by e.g. GALOTTO et al. (2008) it is known that even the smallest changes in molecular weight have a negative effect on mechanical durability of polyolefin films. Considering all of the above and the correlation of structural changes with mechanical durability, the parameters determining mechanical durability can be treated as pointing towards degradation rates, and based on such knowledge all trade specifications are established. From the point of view of the practical business approach those

parameters which determine mechanical properties are extremely useful in terms of analysis and interpretation of changes in functional properties.

The next stage of interpretation of empirical research results focused on the correlation analysis of the impact of critical parameter on the changes of all other tested parameters of polyolefin films' functional properties. A particular focus was put on the impact of the parameters characterizing structural changes on the level of changes of parameters describing mechanical properties. This was achieved by regression analysis, which was performed for all tested polyolefin films including variant I and II of microclimate conditions (different levels of temperature). In the correlation analysis, the explanatory variable (*Y*) was molecular weight (Mw) whereas dependent variable (*X*) was a break load (*P*) and elongation (*W)*. The results of the analysis allowed to create models of regression which are presented in Tables 7.

Based on the models of regression presented in Tables 7 a reaction force of molecular weight changes with changes in break load and elongation at break can be determined. The reaction force can be calculated based on directional factor. With all this in mind, it is possible to state that regardless the microclimate conditions variant used, a change in molecular weight has the strongest impact on elongation. A decrease in molecular weight by 10 units leads to an elongation change, depending on the type of film, between 0,1–5% in case of variant I and 1–6% in case of variant II. The break load does not seem to have such a strong effect on the films with 0,09–1,8 N in variant I and 0,2–0,7 N in variant II.

Conclusions

The analysis of obtained results proves the thesis that microclimate conditions influence the level of changes of parameters characterizing functional value of packaging films. Moreover, the tests conducted on the impact of microclimate conditions on the scope and intensity of changes in properties of polyolefin films allowed us to point out these particular properties which have a significant effect on functional value. With this in mind, only such properties were later analyzed which are responsible for changes within the system: microclimate conditions – packaging material (plastic film). These properties were considered to be critical ones and among them we can find all those parameters that characterize structural changes of films and their mechanical durability, which entails that in practical terms such films will be used in highly efficient packaging machines and should keep the given form intact together with the food product they contain.

Although polyolefin films do not have to meet very specific requirements concerning the evaluation of their functional value and there are no research

procedures to perform such evaluation, it is vital to constantly review the properties characterizing the usability and functionality of food contact materials during storage. This approach is supported by the *Systemy zarządzania...* PN-ISO 22000:2006 and is extremely important for businesses as a means of creating competitive edge.

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FATTY ACID PROFILE OF MILK FAT IN THE LOCAL DAIRY PRODUCTS FROM NORTH-EASTERN POLAND

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K e y w o r d s: fatty acids, milk fat, local dairy products.

A b s t r a c t

The aim of this study was to determine the fatty acid profile of cheese and tvorog milk fat obtained from the local producers from the region of north-eastern Poland. The material consisted of tvorog and cheese samples made from cow, goat and sheep's milk. Methyl esters of fatty acids in milk fat was prepared with the use of IDF Standard 1999 and was performed by the gas chromatography method. Differences were found in the percentage share of each fatty acid group depending on the type of milk from which the cheese was produced. It may be concluded that local tvorog and cheese made from goat's, sheep's and cow's milk from north-eastern Poland may be a valuable source of short- and medium-chain fatty acids as well as CLA.

PROFIL KWASÓW TŁUSZCZOWYCH W TŁUSZCZU MLEKOWYM LOKALNYCH PRODUKTÓW MLECZARSKICH PÓŁNOCNO-WSCHODNIEJ POLSKI

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Abstrakt

Celem badań było określenie profilu kwasów tłuszczowych tłuszczu sera i twarogu uzyskanych od lokalnych producentów z regionu północno-wschodniej Polski. Materiał badawczy stanowiły próbki sera i twarogu wykonane z mleka krowiego, koziego i owczego. Estry metylowe kwasów tłuszczowych w tłuszczu mleka przygotowano z zastosowaniem metody IDF Standard 1999 oraz przeprowadzono metodą chromatografii gazowej. Stwierdzono różnice w procentowym udziale poszczególnych grup kwasów tłuszczowych w zależności od rodzaju mleka, z którego wytworzono ser. Można stwierdzić, że lokalne twarogi i sery z koziego, owczego i krowiego mleka z północno-wschodniej Polski mogą być cennym źródłem zarówno krótkich i średnich łańcuchów kwasów tłuszczowych, jak i CLA.

Introduction

Nowadays, consumers are searching for the products that offer them some unique sensory properties and nutritional quality, standing out from the products available on the market (RADZYMIŃSKA et al. 2008). Among such products one can count those made by the local producers of raw materials coming from the region. The notion "local" should be understood as an area located in a proximity to a target consumer and availability on a local market, which in turn creates a specific relation between a producer and a consumer. Consumers are being urged to support local farmers, sustain the regional food supply, and consume a healthier diet through the purchase of local foods directly from producers and the production of seasonally- and geographically-appropriate foods that have been grown and raised at home or in the local community garden. Indeed, the "turn to quality" discourse has become an integral component of local food consumption (WINTER 2003).

Quality control, and related to this evaluation of the authenticity of the products manufactured by the local producers, in this case, is particularly important. Important factors in determining the quality of local dairy products such as milk, butter and cheese are lipids and fatty acids. A unique characteristic of milk fat is the presence of the short chain fatty acids, which are a source of readily available energy. The most important are essential fatty acid (C18:2, C18:3), which serve a number of significant functions, including structural and bioregulation functions (PIETRZAK-FIEĆKO et al. 2007). Recently, intensive research has also been conducted on trans fatty acids and conjugated linoleic acids (CLA) in sheep and goats milk and milk products, because of the beneficial effects of CLA isomers on human health and the putative negative effects of trans isomers (SCINTU and PIREDDA 2007).

It is characteristic for the local dairy production to use the raw materials from a variety of animals including sheep and goat. However, goat's or sheep's milk and its products (including cottage and ripening cheese), despite their

popularity in the European countries, have just started to be recognized in Poland (DMYTRÓW et al. 2010).

Therefore, the objective of the study was to determine the fatty acid profile in cheese and tvorog milk fat obtained from the local producers and local raw materials from the region of north-eastern Poland.

Material and Methods

Selection of samples of local dairy products

The selection of samples of cottage and ripening cheese for analysis of fatty acid profile was performed in the first half of 2011 based on the database created by the Chair of Commodity Science and Food Analysis, University of Warmia and Mazury in Olsztyn. The database was created based on numerous individual interviews aimed at collecting information on local products made from goat's, cow's and sheep's milk currently manufactured in agrotourist farms and small and medium-sized local plants.

This database included basic information on manufacturers, general description of their products, origin of raw materials, sale points or details that might influence purchase of raw materials. The study included exclusively the products which were made of raw material of local origin. In the presented study, all dairy products were obtained in the same season and, therefore, seasonal variations were not expected.

Samples

The research material consisted 11 samples of tvorog (7 samples of tvorog from cow's milk and 4 from goat's milk) and 14 samples of cheese made from cow goat and sheep's milk (8 samples cheese made from cow milk, 4 from goat milk and 2 from sheep milk).

Analytical conditions

Fat from tvorog and cheese were separated by the Schmid-Bądzyński-Ratzlaff method, following a description provided by PRZYSŁAWSKI (2009). The method is based on the release of fat from proteins using hydrochloric acid, followed by extraction with organic solvents: ethyl ether, petroleum ether.

After the fat was extracted, the fatty acid profile was determined in it by the IDF Standard method (1999). Methyl esters of fatty acids were obtained:

solvent and KOH in methanol was added to a weight amount of fat. $NaHSO_4$ was then added and the result was centrifuged. The methyl esters obtained in the process were analysed.

Separation of the examined compounds was performed by gas chromatography using gas chromatographer: HP 6890; flame ionization detector (FID); capillary column with a length – 100 m, inside diameter of 0.25 mm; temperature: detector – 250°C, dispenser – 230°C and column – 60C (1 min) to 180°C (Δt 5°C/min); carrier gas – helium, flow rate – 1.5 cm^3/min, split 50:1.

The identification of fatty acids was carried out on the basis of their retention time in relation to the retention time of standards of fatty acid methyl esters. For this purpose, a mixture of 37 standards of Supelco 37 Component FAME Mix. For the calculation of the percentage share of fatty acids the Chemostation computer program was used. Descriptive analysis was used to calculate means and standard deviation.

Results and Discusion

Both in tvorog and ripening cheese the differences in the content of saturated (SFA) and unsaturated fatty acids were detected depending on the type of milk used to manufacture the products (Table 1, Table 2). The composition of fatty acids in dairy products varies considerably according to environmental factors, farming practice, and genetic and physiological factors related to animals (COLLOMB et al. 2006, LEDOUX et al. 2005).

The content of SFA in total fat in the samples of tested tvorog was on average 70% with a slightly higher content in the products made of goat's milk. In the case of ripening cheese made of goat's and sheep's milk the content of SFA was by over 4% lower than in the products made of cow's milk. The main SFA found in fat extracted from the products made of cow's, goat's and sheep's milk included C16:0, C18:0 and C14:0 acids, similarly to the data presented by other authors (NEUPANEY et al. 2003).

Presence of short- and medium-chain fatty acids (SCFA) is typical of milk: the series of acids from C4:0 to C12:0 has been recognized as milk fat component with properties beneficial to health (WHIGHAM et al. 2000). The significantly high content of SCFA was detected in the samples of fat extracted from goat tvorog (21.60% in total fat) and goat rennet cheese (20.34% in total fat). In the products made of cow's milk the average content of SCFA was 14.67% in total fat in tvorog made of cow's milk and 15.23% for ripening cheese made of cow's milk. RUTKOWSKA et al. (2009) reported a significantly lower content of SCFA in fat of cheese that originated from the dairy plants in the northern, eastern and central Poland, especially in fat extracted from goat

Table 1
Fatty acid composition and *trans* fatty acid content of analysed tvorogs (mean ± standard deviation)

Fatty acids (g/100g of fat)	Tvorog made from cow milk (n = 7)	Tvorog made from goat milk (n = 4)
C4:0	3.56 ± 0.28	2.57 ± 0.14
C6:0	2.40 ± 0.09	2.58 ± 0.22
C8:0	1.53 ± 0.04	2.89 ± 0.39
C10:0	3.36 ± 0.15	9.47 ± 1.45
C11:0	0.07 ± 0.01	0.10 ± 0.01
C12:0	3.75 ± 0.26	3.99 ± 0.66
C13:0izo	0.08 ± 0.02	0.02 ± 0.01
C13:0	0.21 ± 0.02	0.16 ± 0.01
C14:0izo	0.13 ± 0.02	0.10 ± 0.01
C14:0	11.26 ± 0.29	10.07 ± 0.55
C15:0izo	0.30 ± 0.03	0.24 ± 0.04
C15:0aizo	0.60 ± 0.05	0.43 ± 0.04
C15:0	1.27 ± 0.07	0.84 ± 0.57
C16:0izo	0.29 ± 0.13	0.29 ± 0.02
C16:0	28.20 ± 1.88	25.82 ± 1.27
C17:0	0.66 ± 0.29	0.61 ± 0.41
C18:0	11.25 ± 0.87	11.47 ± 2.61
C19:0	0.20 ± 0.02	0.19 ± 0.03
Σ **SFA**[a]	**69.09 ± 4.52**	**71.83 ± 8.42**
C10:1	0.32 ± 0.02	0.20 ± 0.04
C12:1	0.04 ± 0.01	0.03 ± 0.01
C14:1	0.91 ± 0.07	0.35 ± 0.46
C16:1	0.87 ± 0.57	0.38 ± 0.26
C17:1	0.12 ± 0.14	0.14 ± 0.17
C18:1 c9	20.49 ± 0.84	19.94 ± 1.57
C18:1c11	0.66 ± 0.09	0.52 ± 0.06
C18:1c12	0.18 ± 0.03	0.19 ± 0.08
C18:1c13	0.11 ± 0.02	0.06 ± 0.02
C20:1	0.10 ± 0.04	0.05 ± 0.02
Σ **MUFA**[b]	**23.80 ± 1.82**	**21.86 ± 2.67**
C18:2	1.41 ± 0.30	1.95 ± 0.55
C18:3	0.57 ± 0.21	0.40 ± 0.14
CLA*c*	0.71 ± 0.37	0.54 ± 0.14
Σ **PUFA**[d]	**2.68 ± 0.88**	**2.89 ± 0.82**
t6+t9	0.44 ± 0.03	0.43 ± 0.07
t10+t11	2.44 ± 0.90	1.65 ± 0.40
t12	0.28 ± 0.04	0.25 ± 0.05
t16	0.38 ± 0.06	0.29 ± 0.03
t13c9	0.21 ± 0.03	0.20 ± 0.03
t12c9	0.21 ± 0.02	0.23 ± 0.05
t9c12	0.04 ± 0.01	0.03 ± 0.01
t11c15	0.27 ± 0.07	0.13 ± 0.05
Σ **TFA**[e]	**4.27 ± 1.16**	**3.19 ± 0.67**

Explanations: [a]SFA – saturated fatty acid; [b]MUFA – monounsaturated fatty acid; [c]CLA – conjugated linoleic acid; [d]PUFA – polyunsaturated fatty acid; [e]TFA – trans fatty acid

Table 2
Fatty acid composition and *trans* fatty acid content of analysed cheeses (mean ± standard deviation)

Fatty acids	Cheese made from cow milk (n = 8)	Cheese made from goat milk (n = 4)	Cheese made from sheep milk (n = 2)
1	2	3	4
C4:0	3.27 ± 0.91	2.48 ± 0.35	3.17 ± 0.52
C6:0	2.31 ± 0.61	2.42 ± 0.15	2.41 ± 0.12
C8:0	1.68 ± 0.71	2.60 ± 0.24	1.98 ± 0.08
C10:0	4.03 ± 2.74	8.45 ± 1.33	5.61 ± 0.36
C11:0	0.07 ± 0.04	0.13 ± 0.03	0.13 ± 0.05
C12:0	3.87 ± 0.64	4.26 ± 1.59	4.54 ± 1.09
C13:0izo	0.07 ± 0.03	0.04 ± 0.03	0.07 ± 0.04
C13:0	0.19 ± 0.05	0.19 ± 0.04	0.23 ± 0.06
C14:0izo	0.10 ± 0.07	0.10 ± 0.01	0.13 ± 0.04
C14:0	8.35 ± 5.23	10.66 ± 0.93	11.83 ± 1.78
C15:0izo	0.27 ± 0.08	0.23 ± 0.05	0.31 ± 0.11
C15:0aizo	0.52 ± 0.14	0.41 ± 0.07	0.63 ± 0.12
C15:0	1.18 ± 0.30	1.19 ± 0.15	1.39 ± 0.04
C16:0izo	0.32 ± 0.08	0.27 ± 0.03	0.35 ± 0.06
C16:0	30.89 ± 3.23	26.12 ± 1.61	28.28 ± 4.90
C17:0	0.49 ± 0.41	0.77 ± 0.12	0.39 ± 0.55
C18:0	9.84 ± 1.57	11.54 ± 3.33	10.16 ± 1.94
C19:0	0.19 ± 0.03	0.20 ± 0.03	0.28 ± 0.05
C20:0	0.19 ± 0.06	0.27 ± 0.09	0.21 ± 0.07
Σ SFA[a]	**67.82 ± 16.93**	**72.31 ± 10.18**	**72.04 ± 11.99**
C10:1	0.29 ± 0.09	0.22 ± 0.06	0.22 ± 0.07
C12:1	0.04 ± 03.01	0.03 ± 0.01	0.03 ± 0.01
C14:1	0.82 ± 0.36	0.15 ± 0.07	0.15 ± 0.16
C16:1	0.98 ± 0.62	0.60 ± 0.20	0.60 ± 0.08
C17:1	0.19 ± 0.13	0.27 ± 0.02	0.27 ± 0.04
C18:1 c9	21.66 ± 6.11	20.32 ± 2.79	20.32 ± 5.02
C18:1 c11	0.69 ± 0.27	0.48 ± 0.11	0.48 ± 0.18
C18:1 c12	0.23 ± 0.13	0.17 ± 0.08	0.17 ± 0.08
C18:1 c13	0.09 ± 0.02	0.05 ± 0.01	0.05 ± 0.04
C20:1	0.14 ± 0.07	0.03 ± 0.03	0.03 ± 0.01
Σ MUFA[b]	**25.13 ± 7.81**	**22.31 ± 3.37**	**22.31 ± 5.68**
C18:2	2.12 ± 1.40	1.65 ± 0.34	1.36 ± 0.10
C18:3	0.50 ± 0.18	0.45 ± 0.15	0.53 ± 0.09
CLAc	0.60 ± 0.35	0.46 ± 0.18	0.72 ± 0.17
Σ PUFA[d]	**3.22 ± 1.93**	**2.56 ± 0.67**	**2.61 ± 0.36**
t16	0.31 ± 0.07	0.32 ± 0.04	0.45 ± 0.11

cont. table 2

1	2	3	4
t13c9	0.19 ± 0.05	0.21 ± 0.06	0.32 ± 0.13
t12c9	0.24 ± 0.06	0.22 ± 0.06	0.27 ± 0.06
t9c12	0.06 ± 0.07	0.03 ± 0.01	0.06 ± 0.01
t11c15	0.19 ± 0.12	0.17 ± 0.08	0.51 ± 0.09
t6+t9	0.53 ± 0.33	0.38 ± 0.04	0.49 ± 0.11
t10+t11	1.96 ± 0.93	1.28 ± 0.55	3.72 ± 0.42
t12	0.36 ± 0.31	0.21 ± 0.05	0.35 ± 0.12
Σ **TFA**[e]	**3.83** ± **1.95**	**2.81** ± **0.89**	**6.16** ± **1.07**

Explanations: [a]SFA – saturated fatty acid; [b]MUFA – monounsaturated fatty acid; [c]CLA – conjugated linoleic acid; [d]PUFA – polyunsaturated fatty acid; [e]TFA – trans fatty acid

cheese. The results confirm the statement proposed by ALONSO et al. (1999) who assumed that dairy products made of goat's milk had a high content of two fatty acids, i.e. C8:0 and C10:0, in comparison with the products made from cow's milk. This phenomenon was detected in both cottage and ripening cheese.

It was demonstrated that the content of monounsaturated fatty acids (MUFA) in fat of tvorog made of cow's milk was app. 23.80% and was slightly higher than in the products made of goat's milk. A similar tendency, i.e. higher content of this group of fatty acids in total fat in the products made of cow's milk (25.13%), was reported for ripening cheese (Table 1, Table 2).

Among unsaturated fatty acids, polyunsaturated fatty acids (PUFA) play an important role because of their physiological functions. C18:2 was the most prevalent and constituted from 1.36% (in sheep rennet cheese) to 2.12% (in cow rennet cheese) in total fatty acids depending on raw material and type of products (Table 2).

CLAs which are found primarily in food derived from ruminants, such as dairy products and beef, which represent a mixture of positional and geometric isomers of linoleic acid (18:2 cis-9, cis- 12) which contain conjugated double bonds. Data from experimental studies suggests several biological activities of CLA, such as anti-carcinogenic properties, alteration of blood levels of cholesterol and modulation of the immune system (PARIZA et al. 2001, WHIGHAM et al. 2000).

Tvorogs, made of goat's milk, had a higher content of PUFA as compared to the products made of cow's milk. However, this relation was reversed for CLA (Table 1). Among the samples of tvorog made of cow's and goat's milk tested for the composition of fatty acids, the highest content of CLA, i.e. 1.3%, was detected in tvorog made of cow's milk. In dairy products manufactured with cow's milk, the content of CLA was more diversified with the lowest value of

0.20% of total fatty acids in one of the samples. In the case of goat cheese, the content of CLA was on a more comparable level – reaching on average 0.54% of total acids. White cheese produced in Bulgaria from goat's milk contained only 0.5% CLA (MICHAJLOVA 2007). In the fat of fresh sheep cheese, the content of CLA is much higher, i.e. approximately 1.7% (NUDDA et al. 2005). Among the tested types and varieties of cheese, the content of CLA was highest in Italian Pecorino sheep cheese amounting to 0.8 mg per 100 g of fat (PRANDINI et al. 2007). Other Italian varieties of sheep cheese contained even higher amounts of CLA – ranging from 1.0 to 2.5% of total acids (CABIDDU et al. 2006).

The highest content of CLA was detected in fat of ripening cheese made of sheep's milk (on average over 0.72% of total fat), whereas in other cases the proportion of CLA in the profile of fatty acids was lower: 0.60% in fat of cow cheese and 0.46% in fat of goat cheese. The studies conducted by BARAN et al. (2011) also demonstrated a higher content of CLA in the total profile of fatty acids in ripening sheep cheese in comparison with its content in cheese made of goat's milk and from a mixture of goat's and sheep's milk (Table 2).

There is a growing interest in geometric isomers of unsaturated fatty acids in trans-configuration (TFA) found in milk fat because of their harmful impact on human health (JUTTELSTAD 2004). TFA present in milk and meat derived from ruminants constitute from 1% to 8% of total fatty acids. The content of TFA in milk fat changes with season, with higher contents reported in summer when animals graze and a lower amount is detected in winter when they are fed with feedstuffs (FELKNER-POŹNIAKOWSKA et al. 2012).

In the tested group of products, significantly higher content of TFA, i.e. over 6%, was detected in ripening cheese made of sheep's milk, while the lowest content was found in cottage and ripening cheese made of goat's milk in which it did not exceed 3% of total fatty acids (Table 1, Table 2).

Conclusions

Today's consumers are looking for natural, traditional food processed as little as possible which has specific sensory features and documented quality. With reference to the present studies, it may be concluded that local tvorog and cheese made from goat's, sheep's and cow's milk from north-eastern Poland may be a valuable source of short- and medium-chain fatty acids as well as CLA.

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MEAT OF TRADITIONAL AND ALTERNATIVE POULTRY SPECIES IN THE CATERING INDUSTRY

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K e y w o r d s: traditional poultry species, alternative poultry species, catering industry, poultry meat.

A b s t r a c t

This study discusses the popularity of meat from traditional and alternative poultry species in the catering industry. Data for analysis was obtained directly from questionnaires filled out by persons who were responsible for the selection of food ingredients in catering establishments. The respondents were asked about the use of traditional and alternative poultry species in their restaurants and the effect of menu items containing alternative poultry meat on business results.

Chicken meat was the most popular type of poultry that was served by all surveyed facilities (100%), followed by turkey meat (83%). The meat of alternative poultry species, including quail and helmeted guineafowl (43%) and pheasant (20%), was less frequently served on account of its lower popularity among consumers and a high price. The average price per serving was determined at PLN 13.16 for chicken, PLN 32.15 for quail, PLN 31.77 for pheasant and PLN 30.00 for guineafowl. Despite the fact that the meat of alternative poultry species is rarely served by catering establishments, nearly 75% of the surveyed facilities claimed that its presence in the menu improves business results.

MIĘSO DROBIU TYPOWEGO I ALTERNATYWNEGO W GASTRONOMII

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Abstrakt

W pracy oceniano wykorzystanie mięsa drobiu typowego i nietypowego w gastronomii. Dane pozyskano bezpośrednio za pomocą kwestionariuszy ankietowych. Respondentami były osoby odpowiedzialne za wybór surowców w zakładzie. Pytania dotyczyły wykorzystania drobiu typowego i nietypowego oraz wpływu stosowania drobiu nietypowego na efektywność działania lokalu.

Najczęściej stosowano w gastronomii mięso kurczaka, używają go wszystkie badane zakłady (100%), oraz indyka (83%). Wśród drobiu nietypowego w równej ilości zakłady korzystają z przepiórek i perlic (43%), mniej z bażantów (20%). Wpływa na to mała powszechność drobiu nietypowego oraz jego cena, zbyt duża dla konsumentów. Średnia cena porcji kurczaka (13,16 zł) w porównaniu ze średnią ceną porcji przepiórki (32,15 zł), bażanta (31,77 zł) czy perlicy (30,00 zł) jest znacznie niższa. Mimo faktu, że drób nietypowy pojawia się sporadycznie, to jego obecność w ofercie pozytywnie wpływa na działalność zakładu gastronomicznego, stwierdziło tak prawie 3/4 właścicieli lokali.

Introduction

Poultry meat was a specialty of Polish cuisine in the past. Until recently. pheasant, quail and helmeted guineafowl were regarded as expensive delicacies. The status of alternative poultry meat began to change when Poland joined the European Union. Food suppliers have to cater to the consumer's needs in order to generate profits and survive on Europe's increasingly competitive food market (TRZISZKA et al. 2006).

Contemporary consumers are increasingly likely to explore new foods and flavors KWIATKOWSKA and LEVYTSKA 2007). The growing interest in novel foods prompts catering businesses to reach for long-forgotten ingredients and recipes, and it encourages poultry breeders to expand their product range. The supply of alternative poultry species, including pigeons, helmeted guineafowls, quails and pheasants, is on the rise. In view of the above, the objective of this study was to evaluate the popularity of traditional and alternative poultry species in the catering industry.

Materials and Methods

The data obtained during the tests directly in catering establishments using survey questionnaires. The respondents were people who by their functions in the plant had the highest-rated knowledge on the use of the different types of raw materials (including poultry) – owners or chefs. The questionnaire was designed with 15 questions of which only a fraction has been included in the present study. The questions were closed type with a choice of one answer. In three of the questions and respond applied based on the Likert scale. The study analyzed 135 pieces total units: restaurant – 40 pcs., pensions and – 45 pcs., houses wedding – 30 pcs., inns – 40 pieces. The results were processed using Microsoft Excel 2010.

Results and Discussion

The selection of foods served by the surveyed facilities is presented in Table 1. The results of the survey indicate that poultry is highly popular in the catering industry. Chicken meat was the most popular type of poultry that was served by 100% of the analyzed establishments. It was followed by turkey meat (83.33%) that was not served by 28.57% restaurants and 16.67% wedding centers in the group of surveyed facilities. An analysis of waterfowl species revealed that geese and ducks enjoyed similar popularity and were served by more than 50% of the surveyed establishments. Goose meat was somewhat more popular than duck meat in wedding centers and inns. Similar results were reported for helmeted guineafowls and quails which were served by less than half of the analyzed facilities. Pheasants were the least popular poultry species that were found in the menus of only 20% of catering facilities. Pheasant meat was served sporadically in the majority of the surveyed establishments. The meat of pheasants and helmeted guineafowls was not included in the menus of any of the analyzed inns. Pigeon meat is a relatively popular food item at home and in regional cuisine, but despite the above, it was not served by any of the surveyed catering facilities.

Table 1

Poultry meat most frequently served by catering facilities [%]

Specification			Total	Restaurant	Boarding house	Wedding center	Inn
Type of poultry	traditional	chicken	100.00	100.00	100.00	100.00	100.00
		turkey	83.33	71.43	100.00	83.33	100.00
		goose	56.67	50.00	42.86	83.33	66.67
		duck	53.33	57.14	57.14	50.00	33.33
	alternative	quail	43.33	50.00	28.57	50.00	33.33
		pheasant	20.00	7.14	28.57	50.00	0.00
		helmeted guineafowl	43.33	42.86	42.86	66.67	0.00
		pigeon	0.00	0.00	0.00	0.00	0.00

The availability of various types of poultry meat in the investigated restaurants is presented in Table 2. In most of the surveyed facilities, dishes based on the meat of traditional poultry species were listed in the main menu. In all restaurants, chicken and turkey were available only as part of the main menu. In some facilities, the meat of waterfowl species, including geese and ducks. was listed in the main menu. whereas in other restaurants, it was available only on special order.

Table 2

Availability of poultry meat in the offer of catering establishments [%]

Specification			Total	Restaurant	Boarding house	Wedding center	Inn
Menu	traditional	chicken	100.00	100.00	100.00	100.00	100.00
		turkey	83.33	71.43	100.00	83.33	100.00
		goose	23.33	21.43	14.29	33.33	33.33
		duck	33.33	21.43	42.86	50.00	33.33
	alternative	quail	33.33	42.86	28.57	0.00	33.33
		pheasant	13.33	7.14	28.57	16.67	0.00
		helmeted guineafowl	30.00	35.71	28.57	33.33	0.00
		pigeon	0.00	0.00	0.00	0.00	0.00
Special order	traditional	chicken	0.00	0.00	0.00	0.00	0.00
		turkey	0.00	0.00	0.00	0.00	0.00
		goose	33.33	28.57	28.57	50.00	33.33
		duck	20.00	35.71	14.29	0.00	0.00
	alternative	quail	10.00	7.14	0.00	33.33	0.00
		pheasant	6.67	0.00	0.00	33.33	0.00
		helmeted guineafowl	13.33	7.14	14.29	33.33	0.00
		pigeon	0.00	0.00	0.00	0.00	0.00

The availability of alternative poultry meat was characterized by a supply profile in the analyzed establishments. Dishes based on alternative poultry meat were listed in the menu of approximately 2/3 of the surveyed restaurants, and they were available on special order in the remaining 1/3 of the examined facilities. It should be noted that meat served on special order does not contribute to the popularity for less known poultry species because consumers are reluctant to reach for products they are not familiar with (GRUNERT 1996, ISSANCHOU 1996).

A comparison of the above data with the results indicating the popularity of various types of poultry meat among the clients of catering outlets reveals significant discrepancies (Table 3). Chicken was the most popular poultry meat in all of the surveyed facilities, and it was the only item with balanced supply and demand. The demand for the remaining types of poultry meat was significantly lower, which could be attributed to fact that alternative poultry, in particular waterfowl species, is absent from traditional Polish cuisine. Surprisingly, the study also revealed a relatively low demand for turkey meat.

The demand for alternative poultry meat was very low. In this group of products, the meat of the helmeted guineafowl was most popular with clients

in the surveyed establishments. The above can be attributed to low levels of knowledge about the meat of alternative poultry species among consumers.

Table 3

Poultry meat most popular among consumers [%]

Specification			Total	Restaurant	Boarding house	Wedding center	Inn
Type of poultry	traditional	chicken	100.00	100.00	100.00	100.00	100.00
		turkey	36.67	21.43	28.57	83.33	33.33
		goose	13.33	21.43	0.00	0.00	33.33
		duck	13.33	14.29	14.29	16.67	0.00
	alternative	quail	13.33	7.14	28.57	16.67	0.00
		pheasant	10.00	7.14	14.29	16.67	0.00
		helmeted guineafowl	26.67	28.57	14.29	50.00	0.00
		pigeon	0.00	0.00	0.00	0.00	0.00

Restaurant menus generally reflect consumer preferences. The trends in menu offerings are largely determined by consumers who search for outlets that guarantee the most satisfactory sensory experience (BABICZ-ZIELIŃSKA 2000, BABICZ-ZIELIŃSKA and ZABROCKI 2007, EARLE et al. 2007).

The low popularity of alternative poultry meat among restaurant clients can also be attributed to the high price of those products (CHMIELEWSKA 2000. JEŻEWSKA-ZYCHOWICZ 2004, KWIATKOWSKA and LEVYTSKA 2007, NOWAK and TRZISZKA 2006). The average price per one serving of chicken was PLN 13.16 whereas the average prices of alternative poultry dishes were significantly higher at PLN 32.15 for quail. PLN 31.77 for pheasant and PLN 30.00 for helmeted guineafowl (Table 4). A comparison of different types of surveyed facilities indicates that the highest poultry prices were charged by inns.

The data shown in Table 5 illustrates the effect of menu items containing alternative poultry meat on business results. According to the majority of respondents, the availability of dishes based on alternative poultry had a positive influence on business performance. The highest number of respondents arguing that alternative poultry dishes had a definitely positive effect on business performance were representatives of inns, whereas the representatives of wedding centers were least likely to share the above opinion. At the same time, wedding center respondents were most likely to agree that alternative poultry had a positive influence on business results. Neutral responses claiming that alternative poultry had a somewhat positive effect on business were given by 14 to 21 of the analyzed catering establishments, excluding inns.

Only representatives of restaurants (7 respondents) claimed that alternative poultry did not contribute to an improvement in business performance. The noted results seem to suggest that consumers have a growing interest in foods characterized by high quality, supreme sensory attributes and a high nutritional value (GRĘBOWIEC 2010, NOWAK et al. 2008, WIELEWSKA 2004).

Table 4

Price per one serving of poultry meat [PLN]

Specification			Average	Restaurant	Boarding house	Wedding center	Inn
Type of poultry	traditional	chicken	13.16	12.35	11.60	12.00	16.70
		turkey	15.83	15.40	14.40	15.20	18.30
		goose	19.78	17.60	17.00	18.00	26.50
		duck	18.33	17.80	17.50	18.00	20.00
	alternative	quail.	29.65	28.50	37.50	20.00	32.60
		pheasant	32.07	32.00	29.90	34.30	–
		helmeted guineafowl	30.00	28.90	31.30	29.80	–
		pigeon	–	–	–	–	–

Table 5

The effect of menu items containing alternative poultry meat on business results [%]

Specification	Total	Restaurant	Boarding house	Wedding center	Inn
Definitely yes	43.33	42.86	42.86	33.33	66.67
Yes	36.67	28.57	42.86	50.00	33.33
Neither yes nor no	16.67	21.43	14.29	16.67	0.00
No	0.00	0.00	0.00	0.00	0.00
Definitely not	3.33	7.14	0.00	0.00	0.00

Conclusions

1. The meat of traditional poultry species was served by the surveyed catering facilities in considerably larger amounts than alternative poultry meat which accounted for a small part of their menu offerings. Alternative poultry meat remains relatively unpopular among consumers.

2. The low demand for the meat of alternative poultry species can be attributed mainly to the high price of those products.

3. Despite the fact that alternative poultry meat is sporadically served by catering establishments, nearly 75% of the respondents were of the opinion that the presence of alternative poultry in the menu had a positive effect on business results.

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OSMOLALITY OF ISOTONIC DRINKS IN THE ASPECT OF THEIR AUTHENTICITY

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K e y w o r d s: isotonic drinks, osmolality, authenticity of product.

A b s t r a c t

Isotonic drinks belong to a group of products which are becoming more and more popular among teenagers, sportsmen, as well as the elderly and fitness-oriented people. The proper osmolality of isotonic drinks should be of 300 mOsm kg^{-1} of water ±10%. The objective of this study is to analyse whether the isotonic drinks available on the Tricity market (the area of three cities: Gdańsk, Sopot, Gdynia) are authentic isotonic drinks. For the purpose of the study 25 bottles of isotonic drinks of different brands and flavours have been purchased. The osmolality of the majority of the drinks was within the recommendations of European Union – from 270 to 330 mOsm kg^{-1} of water. Twelve of the drinks have not got the osmolality declared by the manufacturers. Six of them have not met the requirements for an isotonic drink (two of these had not been declared to be isotonic drinks). It seems that manufacturers should observe the quite broad limit of osmolality and the criterion of osmolality is the evidence for their authenticity.

BADANIE OSMOLALNOŚCI NAPOJÓW IZOTONICZNYCH W ASPEKCIE ICH AUTENTYCZNOŚCI

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S ł o w a k l u c z o w e: napoje izotoniczne, osmolalność, autentyczność produktów.

A b s t r a k t

Napoje izotoniczne są coraz popularniejszą grupą towarów kupowaną zarówno przez młodzież, sportowców, jak i osoby starsze dbające o swoją formę. Powinny charakteryzować się osmolalnością 300 mOsm kg^{-1} wody ±10%. Celem pracy było stwierdzenie, czy napoje obecne na rynku trójmiejskim

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są autentycznymi izotonikami. Zakupiono 25 napojów izotonicznych różnych marek o wielu smakach. Większość badanych napojów miała osmolalność w granicach rekomendowanych przez Unię Europejską – od 270 do 330 mOsm kg^{-1} wody. Dwanaście napojów nie miało deklarowanej przez producenta osmolalności. Spośród badanych napojów sześć z nich nie spełniało warunków napoju izotonicznego (w tym dwa nie były deklarowane jako izotoniczne). Wydaje się, że dość szeroka granica osmolalności powinna być przez producentów przestrzegana, zaś kryterium osmolalności jest dla napojów izotonicznych wyrazem ich autentyczności.

Introduction

Isotonic drinks belong to a group of functional beverages. It is relatively a new category of products on the domestic market. Due to their properties, isotonic drinks are used to replenish the loss of fluids in a human body, especially after physical work out. These drinks may also be helpful during dehydration therapy. isotonic drinks are intended to restore the loss of water and minerals such as sodium, potassium, calcium and magnesium ions in result of sweating during physical work out. The osmolality of the drinks depends on their ingredients. They contain carbohydrates, ions of sodium, calcium, magnesium, potassium and chloride as well as vitamins, especially B vitamins (AMENDOLA et al. 2004). Due to the fact that osmolality of these drinks is similar to the osmotic pressure of the human blood, the ions and water are absorbed relatively quickly. Previously, the sports drinks of osmolality from 275 to 295 mOsm kg^{-1} of water were considered as isotonic. Currently, according to the European Union regulations, drinks containing the osmolality of 300 mOsm kg^{-1} of water ± 10%, that is from 270 to 330 mOsm kg^{-1} of water are isotonic drinks (Report of the Scientific Committee on Food... 2001). Beverages of lower isotonicity are considered as being hypotonic, and these of higher isotonicity to be hypertonic.

The objectives of the study and grounds for research

Isotonic drinks are in the same groups as energy drinks on the domestic market and their sales rates are calculated together. 80% of the sale of functional drinks includes energy drinks and about 20% are isotonic drinks (the figures may differ slightly for different periods of sale). However, the sale of isotonic drinks has been increasing and it is expected that their sale growth will continue on the market. Supermarkets have been introducing isotonic drinks under their own trade names (private label). This makes the drinks more affordable and available for younger customers. The manufacturers attempt to create an attractive packaging for the drinks (cans, PET bottles of

different volume) and they introduce a variety of flavours and colours of isotonic drinks. This leads to the extension of the offer for customers. The increasing sale of isotonic drinks is also caused by changes in human behaviour. A healthy lifestyle, sports and recreation (e.g. jogging, biking, Nordic walking) are being promoted. The consumers choose isotonic drinks to replenish the amount of water and electrolytes in their bodies.

The market of isotonic drinks is a prospective market. Many new drinks have been introduced into the market. Many of them are of private label and thus of a lower price. Thus the drinks are getting more and more available to low income and young customers. According to Nielsen's report, 26.75 million of litres of isotonic drinks were sold for the price of 149 million PLN in the period from February 2011 to January 2012. (That is 21.4% of the whole isotonic and energy drinks market). With regard to the volume, the sale increased 10.8% in comparison to the period from February 2010 to January 2011 (the sale was 113 million of litres). This might reflect the potential of this market. The packaging of the drinks is also of importance in terms of purchasing. The majority of isotonic drinks packaging are PET bottles of 500 ml volume, a lower number of packagings include 250 ml cans. PET bottles of 750 ml (Oshee) and 700 ml (4move) volume are new on the market. According to TGI research done by Millward Brown Institute SMG/KRC, the most frequently consumed isotonic drink in the period from January 2011 to December 2011 was Powerade (ZASADA 2012). However, according to the research of BŁASZCZYK et al. (2012), the most popular drinks were Powerade and Oshee.

Isotonic drinks are considered as sportsmen's beverages. Many studies are being conducted in order to analyse the influence of different doses of sugars, types of sugars, ions of sodium, potassium and vitamins on the efficiency of a sportsmen's body, their speed and exercising capacity. The research on the optimal composition of isotonic drinks are to provide better results for sportsmen. The ability to replenish fluids in a human body by drinking water and isotonic drinks is also subject to analysis. An insufficient fluid intake results in dehydration of the body. There are three types of dehydration, mild dehydration (about 1% loss of body weight), moderate dehydration (about 4% loss of body weight) and severe dehydration (about 10% loss of body weight which requires emergency care). It is well known that the replenishment of water lost during exercising is one of the most important parameters controlled by coaches and physicians supervising their sportsmen (PASSE et al. 2009, EWANS et al. 2009, HILL et al. 2008).

One of the first researches on isotonic drinks was conducted by a consumer organization and was published in Świat Konsumenta (now ProTest) magazine in 2003 and 2007 (ANONIM 2003, ANONIM 2007). The isotonicity of the

drinks was one of assessment criterions. It is the osmolality that is essential in terms of the authenticity of these drinks.

Therefore, the objective of this study was to confirm the authenticity of isotonic drinks purchased on Tricity market on the basis of their osmolality.

Method

For the purpose of this study, 25 isotonic drinks of different brands have been purchased in supermarkets (Polo, Lidl, Biedronka, Auchan, Delikatesy ALBO) in the area of Tricity and its surroundings to be analysed in terms of their osmolality. Only the beverages available in supermarkets have been taken into consideration. The homemade (powdered) isotonic drinks have not been analyzed. The purchased isotonic drinks included the folowing drinks: Isostar, 4move, BE Sport, Oshee, Kite, Siti, Gatorade, Powerade and Iso Fresh. The drinks have been coded. The osmolality has been measured with Marcel® OS3000 osmometer (product of Poland – Marcel Sp. z o. o.). The reference standard was Funke Gerber calibration standard of the following paramaters: -0.557°C and 300 mOsm. The osmometer measures the exact freezing point of the liquid and the temperature is later calibrated with calibration solution. The drinks had different packagings, the majority of them were PET bottle of 500 ml, 555 ml, 700 ml, 750 ml volume and 250 ml cans. The research was conducted on the drinks in the period from March to April 2013 before their expiry date.

Results and Discussion

The results of the research are presented in Table 1.

Table 1 also shows the value of osmolality declared by a manufacturer. Up to 12 drinks do not provide any information about their osmolality on their labels. It seems that such information should be included on the drink's label because it confirms the isotonicity of the particular drink and also the fact that the manufacturer has examined its essential parameters. Of all analysed drinks, 6 have not had the proper osmolality for their group of drinks, 2 of them have not had any declaration of isotonicity (drinks no. 4 and no. 9). The drinks with non-declared isotonicity have been purchased at the isotonic drinks shelf in the supermarket. This leads to inappropriate recognition by customers. Drinks no. 11 and no. 12 are hypotonic drinks and drinks no. 20 and no. 23 are hypertonic drinks. The differences between the manufacturer's declaration and the osmolality measurement are minor for the majority

of drinks. From 25 analyzed drinks only 19 are authentic isotonic drinks. If the narrower scope of osmolality range, that is 275–295 mOsm kg^{-1} of water, was taken into consideration, only 15 out of 25 drinks would comply with the osmolality criterion. In some opinions, the range of osmolality recommended by European Union is too wide, and therefore only one of the anlayzed drinks may be considered as an isotonic drink (MAUSER 2011).

Table 2 shows the contents of carbohydrates, sugars and sodium declared by the manufacturers of the isotonic drinks. The data in this table confirm that drinks no. 4 and no. 9 are certainly not isotonic drinks as the contents of sugars

Table 1

Osmolality of isotonic drinks

No. of drink	Drink code	Taste	Measured osmolality	Declared osmolality
			[mOsm kg^{-1} of water]	[mOsm kg^{-1} of water]
1	*A*	multifruit	289	288
2	*A*	lemon	297	288
3	*B*	cherry	289	290
4	*B*	apple, white grapes, pear	155	–
5	*B*	arapefruit	290	289
6	*B*	orange	290	285
7	*B*	lime, mint	287	290
8	*B*	lemon	277	290
9	*B*	multifruit	52	–
10	*C*	blueberry	279	–
11	*D*	multifruit	232	–
12	*D*	grapefruit	228	–
13	*E*	blackberry	311	–
14	*E*	lemon	281	–
15	*F*	lemon	281	–
16	*F*	blueberry	283	–
17	*G*	red orange	306	304
18	*G*	mango	288	294
19	*G*	multifruit	293	294
20	*H*	lime, mint	334	307
21	*H*	blueberry	282	284
22	*H*	lemon	287	296
23	*I*	lemon	337	–
24	*I*	orange	305	–
25	*I*	grapefruit	318	–

and carbohydrates differs too much from the contents in other drinks. The value for drink no. 4. is 2.7 g of carbohydrates (incl. 2.7 g of sugars) per 100 ml of the drink and for drink no. 9. is 0 g of carbohydrates (incl. 0.0 g of sugars) per 100 ml of the drink. For the other drinks the contents of carbohydrates is between 3.9 to 6.7 g per 100 ml, including 3.8 to 6.0 g of sugars per 100 ml. The contents of sodium in the analyzed drinks has also been different and has oscillated between 43 and 72 mg per 100 ml of liquid. The majority of the analyzed drinks have had the sodium contents of 45–50 mg/100 ml. The content of sodium influences the osmolality of the drink because sodium ions participate in osmosis.

Table 2
The content of carbohydrates, sugars and sodium in isotonic drinks declared by manufacturers

No. of drink	Drink code	Taste	Carbohydrates	Sugars	Sodium
			[g/100 ml]	[g/100 ml]	[mg/100 ml]
1	*A*	multifruit	6.0	4.3	72
2	*A*	lemon	6.0	4.3	72
3	*B*	cherry	5.7	4.0	45
4	*B*	apple, white grapes, pear	2.7	2.7	<20
5	*B*	grapefruit	5.7	4.0	45
6	*B*	orange	5.7	4.0	45
7	*B*	lime, mint	5.4	3.9	45
8	*B*	lemon	5.7	4.0	46
9	*B*	multifruit	0	0	38
10	*C*	blueberry	5.4	3.8	–
11	*D*	multifruit	5.4	3.8	43
12	*D*	grapefruit	5.4	3.8	43
13	*E*	blackberry	6.0	6.0	50
14	*E*	lemon	6.0	6.0	50
15	*F*	lemon	5.4	3.8	50
16	*F*	blueberry	5.4	3.8	50
17	*G*	red orange	6.0	6.0	50
18	*G*	mango	3.9	3.9	50
19	*G*	multifruit	3.9	3.9	50
20	*H*	lime, mint	6.7	5.8	50
21	*H*	blueberry	5.4	3.8	50
22	*H*	lemon	5.4	3.8	50
23	*I*	lemon	6.7	5.5	70
24	*I*	orange	6.7	5.5	70
25	*I*	grapefruit	6.7	5.5	70

Also the research conducted by *Świat Konsumenta* (2003 and 2007), the isotonicicty has not been stated in the drinks declared to be isotonic drinks (ANONIM 2003, ANONIM 2007). Also the research on osmolality conducted by METTLER et al. confirms that not all of the isotonic drinks have got appropriate rate of osmolality. The Swiss research aimed to analyze the osmolality of purchased liquid drinks as well as powdered drinks to be made at home. The different ranges of osmolality have been also taken into consideration. According to Swiss' law drinks of osmolality of 250–340 mmol/l may be considered as isotonic drinks, whereas the actual range of osmolality for an isotonic drink is 280–290 mmol kg^{-1}. However, even applying the wider range of osmolality, some of the drinks declared as isotonic have not been confirmed as isotonic (METTLER et al. 2006).

As the market of functional drinks has been in a continuous progress the manufacturers have been introducing new isotonic products by adding new flavours or changing the ingredients (4 move has been the first brand in Poland to add stevia). Due to this fact, the osmolality of these drinks should be monitored carefully. It is also essential to analyse any homemade powdered drinks because there is a group of consumers of these products.

The analysis of the osmolality is therefore a verification method for the authenticity of an isotonic drink.

Conclusions

1. The majority of the analysed isotonic drinks have the osmolality rate recommended by the European Union for their group of drinks (300 mOsm kg^{-1} of water ± 10%). This is a proof of their authenticity.

2. The diferrences between the osmolality declared by manufacturers and the measured osmolality are minor.

3. The contents of carbohydrates in the analysed isotonic drinks oscillated between 3.9 and 6.7 g per 100 ml, and the contents of sodium oscillated between 43 and 72 mg per 100 ml of the drink. Both the contents of carbohydrates and sodium determine the rate of osmolality.

4. Isotonic drinks available on the market should be, therefore, monitored in terms of their osmolality.

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THE INFLUENCE OF HYGIENIC QUALITY PARAMETERS ON COMPOSITION AND PHYSICAL PROPERTIES OF OLKUSKA SHEEP MILK*

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K e y w o r d s: sheep's milk, milk composition, physical properties, hygienic quality, correlations.

A b s t r a c t

The aim of this study was to determine the influence of sheep's milk hygienic quality parameters on its composition and physical characteristics. During the three-year study 140 samples of Olkuska sheep milk were collected for analyzes. The samples were taken during the morning milking, and then were tested to determine the composition, physical properties, the presence of inhibitory substances, somatic cell count (SCC) and the total number of microorganisms. The increase in SCC and the total number of microorganisms caused an increase in dry matter content, total protein, casein, fat, total and soluble ash, pH, viscosity, conductivity and freezing point, and a decrease in lactose content, acidity and density. Statistically significant correlations were obtained for the relationship between SCC and the content of casein, fat, acidity, pH, density, and conductivity. As regards the total number of microorganisms most of the correlations were statistically significant, and the calculated correlation coefficients were higher than in case of SCC.

WPŁYW PARAMETRÓW JAKOŚCI HIGIENICZNEJ NA SKŁAD I WŁAŚCIWOŚCI FIZYCZNE MLEKA OWIEC OLKUSKICH

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S ł o w a k l u c z o w e: mleko owcze, skład, właściwości fizyczne, jakość higieniczna, współzależności.

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Abstrakt

Celem badań było określenie wpływu parametrów jakości higienicznej mleka owczego na jego skład i cechy fizyczne. W trakcie trzyletnich badań pobrano do analiz 140 próbek mleka owiec olkuskich. Próbki pobierano z porannego udoju, następnie poddawano badaniom w celu określenia składu, właściwości fizycznych, obecności substancji hamujących, liczby komórek somatycznych (SCC) oraz ogólnej liczby drobnoustrojów. Wzrost SCC i ogólnej liczby drobnoustrojów powodował wzrost zawartości suchej masy, białka ogółem, kazeiny, tłuszczu, popiołu ogólnego i rozpuszczalnego, pH, lepkości przewodności i temperatury zamarzania oraz spadek zawartości laktozy, kwasowości i gęstości. Statystycznie istotne współczynniki korelacji uzyskano dla zależności między SCC i zawartością kazeiny, tłuszczu, kwasowością, pH, gęstością i przewodnością. W odniesieniu do ogólnej liczby drobnoustrojów większość obliczonych zależności była istotna statystycznie, a uzyskane współczynniki korelacji były wyższe niż dla SCC.

Introduction

The hygienic quality of milk is determined on the basis of the presence of inhibitory substances, the total number of microorganisms and the cytological quality, that is somatic cell count (SCC). However, the most frequently used and found in research and literature hygienic quality indicators are the total number of microorganisms and somatic cell count. Their widespread application results from good accuracy of the assessment. At the same time both indicators are closely related and in most cases high total number of microorganisms is accompanied by high number of somatic cells.

Increased total number of microorganisms informs about milk bacterial contamination and as demonstrated SEVI et al. (1999) it is closely related to the occurrence of udder inflammation (mastitis), which is caused by pathogenic organisms, particularly Staphylococcus and Streptococcus. Inflammatory conditions also cause an increase in the number of somatic cells. The milk originating from a healthy udder contains a small number of these cells. The occurrence of disease states, in particular caused by novobiocin-sensitive coagulase negative staphylococci (Streptococcus spp. and Enterococcus spp.), leads to a significant increase in milk leukocytes (produced as a defense reaction of the organism), thus an increase in SCC. Therefore, somatic cell count is widely used as an indirect method of detecting udder inflammatory conditions (ARIZNABARRETA et al. 2002, RAYNAL-LJUTOVAC et al. 2007, SEVI et al. 1999a, TIETZE and MAJEWSKI 1995).

Increased somatic cell count and the total number of microorganisms adversely affect the yield, composition, and physical characteristics of collected milk, as well as the subsequent fermentation processes and the quality of obtained final products. Studies conducted on sheep milk unquestionably confirm the impact of mastitis on milk yield, which is significantly lower

comparing to the quantities of milk obtained from healthy sheep. According to numerous publications losses may range from 3% to 14% of the average milk yield, and depend on the nature of the infection. Losses associated with the production of cheese from milk with a high somatic cell count may be as high as 15.5% (EL-SAIED et al. 1998, GONZALO et al. 1994, 2002, LEITNER et al. 2008, OSIKOWSKI et al. 1999, PELLEGRINI et al. 1997). Furthermore, such cheese is characterized by up to 4% lower content of protein as compared to cheese manufactured from low somatic cell count milk (RAYNAL-LJUTOVAC et al. 2007). Changes in the chemical composition of the milk relate primarily to the components synthesized in mammary gland such as fat, protein and lactose. Chronic mastitis causes a decrease in the fat content, increase in the protein content and at the same time a decline in the casein. This leads to reduction in the casein number – a very important milk quality indicator from the technological point of view. In case of mastitis lactose content is reduced significantly. It is associated with a decrease in the ability to synthesize milk constituents in the infected udder. This is also of great technological importance, since adequate lactose content is necessary for the proper fermentation processes during the production of fermented milk drinks as well as in cheese production. Lower content of calcium and phosphorus, and increased content of chlorine, sodium, and potassium were also found in the milk of sheep with clinical mastitis. The decline in calcium content is particularly worrying, because it affects rennet coagulation process and determines the quality of the clot. The milk clotting time is prolonged and obtained clot is looser. Moreover, in the case of mastitis the pH rises and can even reach 7 as a slightly acidic reaction of milk results from the presence of acidic phosphates and casein (ALBENZIO et al. 2005, BONCZAR 1994, BONCZAR and PACIOREK 1999, CAROPRESE et al. 2006, JURCZAK 2005, KĘDZIOR 2005, PIECZONKA 1999, RAYNAL-LJUTOVAC et al. 2007, SEVI et al. 1999).

As it was demonstrated numerous studies have shown that mastitis causes a decrease in milk yield and affects milk composition. Especially the influence of SCC is well documented. However scientific publications on the statistical relationships of sheep's milk hygienic quality parameters to its physicochemical characteristics are rare. For this reason the aim of this research was to determine the correlations between sheep milk somatic cell count and the total number of microorganisms and its components and physical characteristics.

Materials and Methods

The study was conducted using a flock of Olkuska sheep. The age of sheep ranged from 2 to 8 years. Animals were under two different feeding systems: stable-diet for the first three month of lactation and grazing at the grass

pasture for the rest of the experiment. A single sample of experimental material consisted of milk obtained from individual lacting sheep. Milk was collected at monthly intervals for the first 5 months of lactation to guarantee the sufficient amount of milk for analyzis. All analyzed samples were taken during the morning milking. Until lamb weaning milking was carried out after earlier (about 8 hours) separation of sheep from their lambs. Milking was carried out manually. The milk samples in the glass bottles were placed in cooler boxes and immediately transported to the laboratory where the analyzes were conducted. The study was conducted for three years, a total of 140 samples was analyzed.

Analyzed milk samples were studied to determine the basic composition, physical and hygienic quality. In particular following parameters were determined (*Mleko surowe...* PN-A-86036:1998, *Mleko...* PN-A-86122:1968, *Mleko...* PN-EN ISO 8968-1:2004):

– dry matter content according to the oven-drying method,
– fat content according to Gerber method,
– proteins content according to Kjeldahl method,
– total ash content by dry mineralization in temperature + 525°C,
– soluble ash content callculated as a difference between total ash and ash insoluble in 10% hydrochloric acid,
– lactose content,
– casein content according to Wolker method,
– casein number (the ratio of casein to total protein),
– total (titratable) acidity and pH,
– density by thermolactodensimeter,
– viscosity on Rheotest RN 3.1 apparatus,
– freezing point (temperature) using Funke Gerber cryoscope,
– electrical conductivity,
– presence of inhibitors with STD-Abiotest,
– somatic cell count (SCC) on Fosomatic 360 apparatus,
– the total number of microorganisms on BactoScan 8000 apparatus.

The results were statistically analyzed aiming to determine correlations between the parameters of hygienic quality and other parameters of the overall quality of sheep's milk. Statistical analyzes were performed using The Statistica 8.0 PL software.

Results and Discussion

Inhibitors in this experiment were detected in a few samples for which at the same time both somatic cell count and the total number of microorganisms obteined the highest values. The results confirmed the facts, ie. these sheep

were given antibiotics because of existing strong inflammation of the udder. The milk from these animals was not used for consumption or further processing. Due to the small number of such samples this indicator is not taken into account in further analyzes.

The influence of somatic cell count and the total number of microorganisms was considered in the first place, in relation to the basic components of milk, and then to the physical parameters.

The increase in somatic cell count in the milk of Olkuska sheep was accompanied by an increase in the content of dry matter, total protein, casein, fat, total and soluble ash, the number of casein and a decrease in lactose content. However, statistically significant correlation coefficients related only to the relationship between somatic cell count and the content of casein and fat.

The results concerning the relationship between the total number of microorganisms and basic chemical components of milk were very similar to those calculated for somatic cell count (Table 1). This is due to the fact that bacterial infections are the most common cause of increase in the number of somatic cells. The correlations were also positive (with the exception of relationship with the number of casein), but their strength was distinct. Statistically significant coefficients were calculated for the corelations with dry matter, total protein, casein, fat, total and soluble ash. The highest coefficients, close to 0.5, were obtained for the correlation between the total number of microorganisms and total and soluble ash.

Table 1

Correlations between the basic chemical components of Olkuska sheep's milk and somatic cell count and the total number of microorganisms

Parameter	Somatic cell count	The total number of microorganisms
Dry mass	0,022	**0,357***
Lactose	-0,193	-0,048
Total protein	0,257	**0,319***
Casein	**0,284***	**0,287***
Casein number	0,015	-0,044
Fat	**0,357***	**0,415***
Total ash	0,197	**0,464***
Soluble ash	0,208	**0,483***

* statistically significant correlation coefficient ($\alpha = 0.05$)

The results obtained in the present study regarding the content of dry matter, protein, fat and lactose are consistent with findings by BONCZAR on Poland Longwool variety rząskowska sheep milk (BONCZAR 1994). Also OLECH-

NOWICZ and STEPPA (2000) conducting research on milk of dairy sheep 05 (13/16 Friesian sheep, 3/16 Polish merino) found that milk obtained from animals with healthy glands (somatic cell count below 250000/ml) contained significantly lower amount of protein than milk of animals with inflammation. At the same time the content of lactose was higher. A statistically significant increase in protein and fat and a decrease in lactose content in the milk of infected sheep also found WÓJTOWSKI et al. (1998) and GUT et al. (1999) who examined sheep milk of three synthetic lines among others with varying degrees of participation of East friesian and Polish merino sheep. Calculated correlation coefficients between the log SCC and the percentage content of protein, fat and lactose were 0.354, 0.192 and -0.575 respectively. The increase in protein content due to the increasing number of somatic cells was also observed in milk of churra sheep (EL-SAIED et al. 1998, 1999), for which the correlation coefficient between log SCC and the percentage of protein content was 0.12 and 0.16. Results for correlation with protein content and fat are also consistent with the results of research conducted by RIGGIO et al. (2007) and ALBENZIO et al. (2002) and relating protein with findings by ALBENZIO et al. (2004) LEITNER et al. (2004) and RODRIGUEZ-NOGALES et al. (2007). A statistically significant decrease in lactose content with an increase in SCC confirmed studies by VIVAR-QUINTANA et al. (2006) carried out on milk of Assaf sheep hybrids with churra and castellana sheep. The decrease in lactose content with the increase in the number of somatic cells also corresponds to the findings by other authors, among others by SEVI et al. (1999) for Comisana sheep milk, SINAPISI et al. (2007) or LEITNER et al. (2004) and is associated with a decrease in the ability to synthesis this component in the infected udder. Sinapis et al. analyzing milk of Boutsiko ewes obtained correlation coefficient -0.19.

Similarly to cows milk, the percentage increase in protein content caused by the increasing somatic cell count may be explained by the parallel increase in blood proteins in milk of sheep with bacterial infections (EL-SAIED et al. 1998, 1999, RAYNAL-LJUTOVAC et al. 2007). Such a finding is also reported by other authors who indicate that the increase or no change in protein content in milk despite the decreasing casein content can be explained by an increase in the content of blood serum proteins which are excreted in milk through the loosened epithelial cells of infected animals (ALBENZIO et al. 2005, 2002, SEVI et al. 2001). The increase in the percentage of fat in milk with an increased SCC, whether caused by the occurrence of bacterial inflammation or secretion disorders may be explained by the effect of "dilution", as the amount of fat does not change while the amount of milk from sick animals is greatly reduced (ALBENZIO et al. 2002). Whereas the increase in ash content can be explained by increasing sodium and chloride content in milk of sheep with udder inflammation. This is due to changes in the permeability of cell membranes and the

interstitial spaces that cause the passage of these minerals from the animal's blood to the milk in order to maintain the osmotic equilibrium (BONCZAR 1994, BONCZAR et al. 1994, RAYNAL-LJUTOVAC et al. 2007).

A slight increase in casein content with deteriorating hygienic quality of milk obtained in this experiment has no confirmation in the literature. The presence of mastitis in fact leads to the reduction in the amount of components synthesized in sheep mammary gland and therefore to the decrease in the amount of secreted casein (SEVI et al. 1999, 1999a). Hence, it is likely that the relationship obtained in the experiment is accidental, especially that the correlation coefficients are low.

The influence of somatic cell count in milk on its physical characteristics was analyzed earlier by BONCZAR et al. (1994). She stated an increase in the pH of milk, its viscosity and electrical conductivity and a slight decrease in density in case of sheep udder disease states. The correlation factors, except for the density of milk (0.1), were statistically significant and were approximately 0.3. In addition, a relatively high correlation coefficient (-0.46) was observed for correlation with titratable acidity. In the present experiment the results were similar (Table 2). Statistically significant correlations were found between somatic cell count and pH (0.48), titratable acidity (-0.36), electrical conductivity (0.33) and density (-0.31). Only for viscosity the correlation coefficient was not statistically significant, although the results confirmed an increase in viscosity with increasing number of somatic cells.

Table 2

Correlations between the physical characteristics of Olkuska sheep's milk and somatic cell count and the total number of microorganisms

Parameter	Somatic cell count	The total number of microorganisms
Titratable acidity	**-0,355***	**-0,300***
pH	**0,481***	**0,640***
Density	**-0,309***	**-0,315***
Viscosity	0,127	0,139
Electrical conductivity	**0,333***	**0,431***
Freezing point	-0,083	-0,198

* statistically significant correlation coefficient ($\alpha = 0.05$)

As in the case of somatic cell count increased total number of microorganisms was accompanied by an increase in pH, electrical conductivity, freezing point and viscosity and a decrease in density and titratable acidity. Statistically significant correlations were found for pH, electrical conductivity, titratable acidity and density.

The increase in pH value when somatic cell count increases was reported by RAYNAL-LJUTOVAC et al.(2007) and VIVAR-QUINTAN et al. (2006). VIVAR-QUINTAN et al. also noted lower titratable acidity of milk with somatic cell count above 3000000/ml. Also ALBENZIO et al. (2005) and SEVI et al. (1999) observed a statistically significant increase in pH value with an increase in SCC. This increase was particularly noticeable in milk containing over 1000000 of somatic cells in 1 ml compared to milk from healthy sheep (SCC < 500000/ml). Whereas WÓJTOWSKI et al. (1998) reported no significant differences in pH values of milk from healthy sheep and from those with infected udders. They found, however, impact of SCC on the freezing point. Milk from infected halves of udders was characterized by freezing point at the level of -0.5866, while from healthy at -0.5787. The correlation coefficient between log SCC and the freezing point was 0.132.

Conclusions

The study confirmed the impact of hygienic quality parameters, in particular of somatic cell count and the total number of microorganisms, on the composition and physical properties of sheep's milk. Especially in the case of the total number of microorganisms the majority of the calculated correlation coefficients was statistically significant and had higher values than the one callculated for the correlation with SCC. The deterioration of hygienic quality of Olkuska sheep milk caused an increase in the content of dry matter, total protein, casein, fat, ash, pH, viscosity, conductivity and freezing point and a decrease in lactose content, acidity and density.

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THE EFFECTS OF DIFFERENT ARTIFICIAL LIGHT COLOURS ON THE GROWTH RATE OF EMBRYO AND JUVENILE RAINBOW TROUT *ONCORHYNCHUS MYKISS* (WALBAUM, 1792)*

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K e y w o r d s: aquaculture, light colour, specific growth rate, rainbow trout.

A b s t r a c t

The colour of light is a very important environmental factor that affects fish physiology. The aim of the present study was to evaluate the effects of different colours of light on weight gain, length, condition factor and specific growth rates of the juvenile rainbow trout *Oncorhynchus mykiss*. The study employed fertilized eggs that were exposed separately to seven colour lamps including white (573 nm, control), azure (397 nm), blue (459 nm), green (524 nm), yellow (586 nm), orange (611 nm) and red (742 nm). The experiment was conducted for 5 months (from fertilization until the fish reached 2 g wet weight) at the Sheshpir fish farm (west of Fars province), Iran. After yolk sac absorption, the weight and length of randomly sampled fish were measured monthly. The results showed that weight parameters of fish exposed to yellow (0.562 ± 0.13) and white (0.547 ± 0.13) coloured light were higher ($p \leq 0.05$) than fish subjected to the other colours. The highest length growth was observed in fish exposed to yellow (3.91 ± 0.16) and white (3.61 ± 0.10) light, respectively. The highest growth rate (4.641 ± 0.29) and condition factor (2.00 ± 0.03) were observed in fish maintained under yellow light.

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WPŁYW WYBRANYCH RODZAJÓW BARWY ŚWIATłA NA WZROST EMBRIONÓW I MŁODOCIANYCH STADIÓW PSTRĄGA TĘCZOWEGO *ONCORHYNCHUS MYKISS* (WALBAUM, 1792)

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S ł o w a k l u c z o w e: akwakultura, barwa światła, SGR, pstrąg tęczowy.

A b s t r a c t

Barwa światła stanowi istotny czynnik, który wpływa na pewne procesy fizjologiczne u ryb. Badano wpływ wybranych barw światła na wzrost, długość i specyficzny wskaźnik wzrostu SGR oraz współczynnik kondycji młodocianych stadiów pstrąga tęczowego *Oncorhynchus mykiss*. Eksperyment prowadzono przez pięć miesięcy, od momentu zapłodnienia do uzyskania ryb o masie 2 g w Gospodarstwie Rybackim Sheshpir (zachodnia część prowincji Fars) w Iranie. Poszczególne grupy badawcze podchowywano z zastosowaniem siedmiu różnych barw światła: białej (573 nm), błękitnej (397 nm), niebieskiej (459 nm), zielonej (524 nm), żółtej (586 nm), pomarańczowej (611 nm) i czerwonej (742 nm). Po resorbcji woreczka żółtkowego losowo odłowione osobniki ważono i mierzono na koniec każdego miesiąca. Wykazano, iż najwyższe wskaźniki masy ciała uzyskały ryby eksponowane na żółte (0.562 ± 0.13) i białe światło (0.547 ± 0.13) w porównaniu z rybami podchowywanych w innych barwach światła ($p \leq 0.05$). Najwyższe wskaźniki długości ciała odnotowano również u ryb podchowywanych z zastosowaniem światła o barwie żółtej (3.91 ± 0.16) i białej (3.61 ± 0.10). Ryby eksponowane na żółtą barwę ciała charakteryzowały się najwyższymi wskaźnikami współczynnika wzrostu SGR (4.64 ± 0.29) oraz współczynnika kondycji (2.00 ± 0.03).

Introduction

The rainbow trout *Oncorhynchus mykiss* naturally inhabits the eastern part of the Pacific Ocean, from the Kuskokwim River in Alaska to the Rio Santa Domingo, Baja California, Mexico. It is traditionally cultured all over the world, including Iran (HEYDARNEJAD et al. 2013), and is one of the most important cold water fish species for commercial fisheries and aquaculture.

The three characteristics of light: wavelength (spectral) composition, intensity and duration are very important to fish life, not only in a natural environment, but also in aquaculture facilities. Most species of fish have well-developed light colour sensors, and are very sensitive to specific colours (IMANPOOR et al. 2011). Some light spectra may modulate several physiological and behavioural responses, such as feeding and growth performance (DURAY et al., 1996, DOWING and LITVAK 2000, HEAD and MALISON 2000, OSALDE et al.

2005, KARAKATSOULI et al. 2007, 2008a), reproduction (VOLPATO et al. 2004), sex determination (TURNER 2008), aggression (HOGLUND et al. 2002), larval jaw malformation (COBCROFT and BATTAGLENE 2009), the stress response (VOLPATO and BARRETO 2001), pigmentation, survival, locomotion and early maturation (OSALDE et al. 2005) and behaviour (MARCHESAN et al. 2005, VOLPATO et al. 2004) in fish.

Fish vision and spectra perception are strongly adapted to each species natural habitat and living ethology (CHINEN et al. 2005, KUSMIC and GUALTIERI 2003, POINTER et al. 2005). In natural fish habitats, the wavelength of light penetrating water varies greatly and depends on various physical, biological and chemical factors. For example, the highest survival rate of haddock *Melanogrammus aeglefinus* larvae and common carp *Cyprinus carpio* was observed during rearing with application of green light (RADENKO and ALIMOV 1991, RUCHIN et al. 2002, RUCHIN 2004). Moreover, GIRI et al. (2002) have reported that exposure of the Wallago, *Wallago attu*, to certain visual wavelengths, for example red, reduced fish growth.

In the natural environment, light intensity and background colour affect the ability of fish to detect food and thence, feeding success. Therefore, colour can affect both fish growth and mortality. The impact of light and background colours should, therefore, be considered during fish culture; especially in economically important species. In general, the highest growth rate of fish larvae has been achieved when light conditions and background colour are optimized to contrast feed from the background (HENNE and WATANABE 2003, JENTOFT et al. 2006, STRAND et al. 2007a).

In aquaculture, the positive influence of rearing light colour is economically important because it may affect fish growth and development and therby lead to enhanced efficiency of production. However, the influence of light spectra on growth of embryos and fry of rainbow trout is surprisingly limited. Accordingly, the purpose of the present study was to evaluate the effects of different light spectra on rainbow trout growth and development, from embryo until 2 grams wet weight.

Material and Methods

Experimental details

The experiment was conducted at the Sheshpir fish farm in Iran (west of Fars province). Sixty-four mature specimens of rainbow trout from the stock population, that were exposed to natural light conditions, were randomly caught. The spawners were of 2–5 years, with a weight of 744–3961 g (mean

± S.E.: 1667.78 ± 86.77) and length of 39–65 cm (mean ± S.E.: 50.38 ± 0.74). The fish were maintained for 2 days in water temperature of 8°C until spawning. Feeding was interrupted 24 hours before spawning. During artificial reproduction, collected eggs were fertilized, mixed and distributed randomly into seven separate fiberglass tanks (length, height, width: 60 cm, 30 cm, and 50 cm, respectively). In each fiberglass tank 1000 eggs were incubated under different light colours: white (573 nm, control), azure (397 nm), blue (459 nm), green (524 nm), yellow (586 nm), orange (611 nm) and red (742 nm). All experimental groups were maintained in a water recirculation system (RAS). The water temperature of each tank was kept at 10°C with pH 7.66, while salinity and dissolved oxygen was kept around 2 ppt and 8.99 mg/l, respectively. The nitrite and ammonium nitrate concentration was lower than 0.05 and 0.5 mg/l, respectively. At 24 hours post – fertilization, physically damaged and dead eggs were removed by using a wide pipette. The tanks were connected to outer sleeve pipes to facilitate self-cleaning and waste removal that were cleaned twice a week. According to the methodology of LARSON et al. (2004), a 60 W red lamp was used during all experimental steps (feeding, biometrics and cleaning the tanks) for illumination of the external environment of the laboratory (IMANPOOR et al. 2011). During experiments, time of the lightening was controlled with an automatic timer system with a 14/10 photoperiod.

Light exposure method

The eggs were incubated in seven separated experimental tanks that were exposed to 5 watt fluorescent colour lamps of: white (control), yellow, green, azure, blue, orange and red. The lamps were suspended 25 cm above the water surface of each tank and the photophased automatically as described above. The experiment was conducted over five months (two months as eggs/yolk sac larvae and three months of rearing) from fertilized egg to 2 g wet weight for each light colour. The photoperiod was provided from 06:00 to 20:00 hours and all groups were kept in isolation throughout the experiment. After absorption of the yolk sac, fish were fed with commercial extruded SFT-00 feed (55% crude protein, 12% fat; Chineh, Iran) twenty-four times per day, during the first 20 days of rearing. Thereafter, fish were fed with the SFT-1 pellets (48% crude protein, 12,5% fat; Chineh, Iran) 15 times a day for 30 days. Finally, feeding was conducted using SFT-2 pellets (45% crude protein, 14% fat; Chineh, Iran) ten times per day until the end of the experiment. Feeds were presented to excess with uneaten food being removed thirty minutes after feeding.

Sampling method

To evaluate the growth of fish in the experimental groups 45 specimens were randomly collected from each tank (after 12 hours feed deprivation) for weight measurement using a digital balance (Mitutoyo, Japan). The total length of the fish was recorded by vernier caliper and was analyzed by using a Canon Power shoot SX530 HS digital camera linked to Image Tool Software version 3 (Japan). Then parameters of weight gain, Specific growth rate and Fulton's condition factor of fish were calculated monthly until study end by the following formulas:

*Weight gain (*WG*)*

$$\mathrm{WG} = \frac{100\ (\mathrm{FW} - \mathrm{IW})}{\mathrm{IW}}$$

where:
WG – weight gain [%]
FW – final weight [g]
IW – initial weight [g].

Specific growth rate (SRG)

$$\mathrm{SGR} = \frac{100\ (ln\ \mathrm{W}_t - ln\ \mathrm{W}_i)}{\Delta \mathrm{t}}$$

where:
W_t – the weight in grams at time t
W_i – is the initial weight
ln – stands for natural log
Δt – the duration of exposure of fish to light colour in days.

Fulton's condition factor (K):

$$K = \frac{W \cdot 100}{L^3}$$

where:
W – weight of fish [g]
L – length of fish [cm].

Data analysis was performed using the statistical program *SPSS* version 11.5 using one way ANOVA. Differences ($p < 0.05$) between means were compared by Duncan's multiple range test at $p \leq 0.05$ as the significant level.

Results

Weight gain of fish exposed to different colours of light for a period of 5 months is presented in Table 1. Differences in mean body weights between groups were only detected for experimental groups exposed to white (control) and yellow light for each month throughout the experiment ($p \leq 0.05$). However, no differences in mean body weights of fish subjected to white and yellow light were observed ($p > 0.05$). Lowest weight gain was observed in fish maintained under green light < blue < azure < orange < red (Table 1). Nonetheless there were no differences in overall weight gain between the latter groups.

The mean changes in group length during three month period of observation is presented in Table 2. A similar pattern to that discerned for weight gain was observed, with fish reared under yellow and white light being longer than all other treatment groups ($p \leq 0.05$). Rainbow trout bred using green light were characterized by poorest length gain < blue ≤ azure < orange ≤ red (Table 2). Similar to weight gain, there were however, no diffrerences between the latter groups in length gain.

Table 1
The effect of light colour on weight gain in breeding of juvenile rainbow trout *Oncorhynchus mykiss*

Month / Light	M_1	M_2	M_3
White	3.84 ± 0.10*	1.62 ± 0.08*	0.56 ± 0.13*
Azure	1.95 ± 0.10	0.89 ± 0.09	0.35 ± 0.06
Blue	1.85 ± 0.21	0.85 ± 0.04	0.34 ± 0.06
Green	1.40 ± 0.35	0.68 ± 0.10	0.29 ± 0.10
Yellow	4.14 ± 0.28*	1.60 ± 0.25*	0.55 ± 0.13*
Orange	2.51 ± 0.24	1.10 ± 0.10	0.39 ± 0.08
Red	2.77 ± 0.24	1.21 ± 0.13	043 ± 0.10

M_1 – first month, M_2 – second month, M_3 – third month
* Significant difference with other light ($p < 0.05$)

Table 2
The effect of light colour on length of juvenile rainbow trout *Oncorhynchus mykiss*

Month / Light	M_1	M_2	M_3
White	3.61 ± 0.10*	4.35 ± 0.13*	6.38 ± 0.25*
Azure	2.84 ± 0.06	3.84 ± 0.12	5.75 ± 0.32
Blue	2.78 ± 0.12	3.84 ± 0.17	5.56 ± 0.22
Green	2.65 ± 0.09	2.78 ± 0.13	4.71 ± 0.19
Yellow	3.91 ± 0.16*	4.58 ± 0.19*	6.55 ± 0.38*
Orange	3.22 ± 0.17	4.20 ± 0.15	6.16 ± 0.34
Red	3.23 ± 0.14	4.18 ± 0.12	6.28 ± 0.28

M_1 – first month, M_2 – second month, M_3 – third month
* Significant difference with other light ($p < 0.05$)

The specific growth rate of the fish was characterized by a declining gradient of yellow > white > red > orange > azure > blue > green lights (Table 3). The highest SGR was observed in fish subjected by yellow light, while the lowest SGR was recorded in the experimental group of fish maintained under green light. The SGR parameters in experimental groups showed significant differences in group of fish exposed to the azure, blue and green light in comparison to fish breed under the white and yellow (Table 3), during the first month of breeding ($p \leq 0.05$). In the next month there were no significant differences between treatments ($p > 0.05$) while, by month three post-hatch, fish reared under yellow light were characterized by higher SGRs when compared to the other experimental groups ($p \leq 0.05$). The highest rate of condition factor was observed in fish breed under yellow light, during all experimental period, while the lowest condition factor was identified in fish exposed to the green light of colour, but differences were not significant (Table 4).

Table 3

Effect of light colour on specific growth rate (mean ± S.E.M) of juvenile rainbow trout *Oncorhynchus mykiss*

Month / Light	M_1	M_2	M_3
Green	3.29 ± 0.14*	2.85 ± 0.27	2.38 ± 0.09
Blue	3.45 ± 0.25*	3.10 ± 0.19	2.58 ± 0.14
Azure	3.43 ± 0.26*	3.12 ± 0.15	2.63 ± 0.12
Orange	3.88 ± 0.27	3.46 ± 0.22	2.75 ± 0.14
Red	4.07 ± 0.09	3.47 ± 0.20	2.76 ± 0.156
White	4.52 ± 0.15	3.54 ± 0.17	2.88 ± 0.07
Yellow	4.64 ± 0.29	3.60 ± 0.35	3.17 ± 0.16**

M_1 – first month, M_2 – second month, M_3 – third month
* Significant difference with white and yellow lights
** Significant difference with other lights; (p <0.05)

Table 4

Effect of light colour on condition factor (mean ± S.E.M) of juvenile rainbow trout *Oncorhynchus mykiss*

Month / Light	M_1	M_2	M_3
Green	0.70 ± 0.02	0.92 ± 0.02	1.41 ± 0.05
Blue	0.78 ± 0.033	0.98 ± 0.04	1.48 ± 0.04
Azure	0.79 ± 0.032	0.98 ± 0.05	1.51 ± 0.02
Orange	0.78 ± 0.02	1.04 ± 0.03	1.60 ± 0.05
Red	0.83 ± 0.03	1.07 ± 0.02	1.61 ± 0.03
White	0.88 ± 0.02	1.17 ± 0.03	1.76 ± 0.04
Yellow	0.92 ± 0.04	1.19 ± 0.04	2.00 ± 0.03

M_1 – first month, M_2 – second month, M_3 – third month

Discussion

In aquaculture, light spectra affect fish physiology, stress response, behaviour and consequently growth performace (KARAKATSOULI et al. 2010). The effect of some light colour on growth of rainbow trout could be due to colour preference (LUCHINARI and Pirhonen 2008) and to the proportion of visual pigments in the retina (TSIN and BEATTY 1977). Optimum assimilation efficiency in fish exposed to the yellow light was described by HOANG et al. (2003) and the low feed consumption together with faster growth were observed because of low activity and energy saving for growth (HEYDARNEJAD et al 2013).

Different colours of light have been applied in an attempt to stimulate the growth rate of several fish species (RUCHIN 2004, MARCHESAN et al. 2005, STRAND et al. 2007a, LUCHIARI and FREIRE 2009, LUCHIARI and PIRHONEN 2008). The present study demonstrated that the growth rate of rainbow trout (from fertilization to the fry of 2 g) was significantly affected by light. The weight and length of fish reared under yellow light were highest in the third month of the experiment. Such results were probably connected to the rainbow trout preference to the yellow colour that does not induce the stress in fish and saves the energy required for growth. Similar results on the influence of yellow light on growth and stress response have been reported previously for juvenile rainbow trout but the experimental animals were older and hence larger (15 cm and 32 g wet weight) than used herein (HEYDARNEJAD et al. 2013). As observed herein, the results of HEYDARNEJAD et al. (2013) indicated best growth and also lowest stress in rainbow trout maintained under yellow light.

PAPOUTSOGLOU et al. (2000) described that the body weight of common carp maintained under yellow light was higher than fish held under black and green light. TAMAZOUZT et al. (2000) reported superior growth in weight and length of European perch *Perca fluviatilis* larvae under grey and white light. In contrast, big-belly seahorses (*Hippocampus abdominalis*), expressed no differences in growth or survival when maintained in white, yellow, orange or green tanks (MARTINEZ-CARDENAS and PURSER 2007). Interestingly, red light stimulates feeding of Nile tilapia (*Oreochromis niloticus*), but this does not translate into extra growth (VOLPATO et al. 2013). Nevertheless, mean body weight of Nile tilapia fingerlings bred in blue light was significantly higher than for fish maintained under white or red light (ELSBAAY 2013). Sensitive to yellow and green light, Atlantic herring, *Clupea harengus*, were recorded as feeding most actively under a wavelength of 560 nm which borders both colours (BLAXTER 1999). Larvae of whitefish *Coregonus pollan*, too, were found to be sensitive to green light but insensitive to the longer wavelength red light (DABROWSKI and JEWSON 2001).

The specific growth rate of fish exposed to different colours of light in this study reveals that the growth of fry of rainbow trout is enhanced under yellow light in comparison to other colours. The SGR of fish subjected during the first month to azure, blue and green lights was significantly lower to other experimental groups, but there were no differences in SGR between treatments in second and third months. Yellow light had significant impact on rainbow trout SGRs during present experiment. Significant increases in SGR were also observed for silver perch *Bidyanus bidyanus* and golden perch *Macquaria ambigua* larvae held under yellow and orange lights (GEHRKE 1994).

The present study demonstrated that green light had a negative effect on growth, probably inducing stress, resulting in decreased appetite and, or feed intake. Lower growth rates observed for fish held under darker colours may reflect a negative impact on the visibility of feed in tanks, resulting in lower consumption (STRAND et al. 2007a, STRAND et al. 2007b).

In conclusion, this study shows that yellow light appears to offer advantage during the rearing of embryonic and fry stage rainbow trout up to 2 g. In older fish, colour preference may however, change as suggested by the findings of KARAKATSOULI et al. (2008b). Before supporting the application of yellow light to the commercial setting however, more studies are warranted to determine optimal colour and light intensity (lux).

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OTOLITH FLUORESCENT MARKING OF PIKE (*ESOX LUCIUS* L.) LARVAE

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K e y w o r d s: otoliths, pike, *Artemia salina*, alizarin red S, tetracycline hydrochloride.

A b s t r a c t

The aim of the present study was to verify the feasibility of using live *Artemia salina* nauplii embedded with fluorochromes for the mass marking of pike *Esox lucius* (L.) larvae. In the experiment, pike larvae 6 days post hatch were fed *ad libitum* with nauplii dyed with 600 ppm tetracycline hydrochloride (TC) or 200 ppm alizarin red S (ARS) for 3 or 6 days. The highest percentage of marked fish (100%) and the best quality of this marking was found in the groups fed *A. salina* stained with TC for either 3 or 6 days. In groups fed *A. salina* stained with ARS for 3 or 6 days exhibited a lower percentage of marked fish (ranging from 76.7–88.3%). No significant differences between experimental groups were noted regarding survival rate, final body weight and length of the reared pike larvae.

FLUORESCENCYJNE ZNAKOWANIE OTOLITÓW LARW SZCZUPAKA (*ESOX LUCIUS* L.)

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S ł o w a k l u c z o w e: otolity, szczupak, *Artemia salina*, alizaryna red S, chlorowodorek tetracykliny.

A b s t r a k t

Celem badań było sprawdzenie możliwości wykorzystania żywych naupliusów *Artemia salina* barwionych uprzednio w dwóch fluorochromach do masowego znakowania larw szczupaka *Esox lucius* (L.). W eksperymencie sześciodniowe larwy szczupaka karmiono naupliusami solowca bar-

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wionymi w chlorowodorku tetracykliny (TC) w stężeniu 600 ppm oraz alizarynie red S (ARS) w stężeniu 200 ppm, odpowiednio przez 3 lub 6 dni. Najwyższy procent znakowanych otolitów/ryb (równy 100%) i wysoką jakość znaczków uzyskano w grupach, w których podawano naupliusy barwione TC zarówno przez 3, jak i 6 dni. Z kolei w grupach otrzymujących pokarm barwiony ARS przez 3 lub 6 dni odnotowano niższy odsetek znakowanych osobników (w zakresie 76,7–88,3%). Nie stwierdzono jednocześnie istotnych różnic statystycznych między wartościami przeżywalności oraz końcową masą lub długością ciała larw szczupaka w poszczególnych grupach doświadczalnych.

Introduction

Pike (*Esox lucius* L.) as a piscivorous fish species at the top of the trophic food web that is an attractive prey for fishermen and anglers. It is also a potential fish for use in aquaculture. Pike is a desirable and protected species in many reservoirs due to its significant contribution to the management of fish communities by effectively eliminating planktivorous fish. Stocking of pike are used in bio-manipulation experiments as an indirect tool to reduce the eutrophication process (PREJS et al. 1997). According to data from MICKIEWICZ (2015), pike stocking was practiced in 91% of the fishery farms in Poland. In the year 2014, it was ranked first with regard to the amount of material it released into open waters as a result of stocking actions.

The production of juvenile stages of fish in hatcheries and stocking freshwater reservoirs using these artificially propagated fish is common and provides the opportunity for larvae or fry mass marking. Marked fish can be used to gain an unbiased evaluation of the potential success/failure of stocking actions and for the determination of the effectiveness of natural reproduction. The choice of marking technique for juvenile stages must be able to be applied to a huge number of fish at the same time, be minimally stressful and ensure that the marks are easy to read after several months or even years (BROWN and HARRIS 1995).

In the case of juvenile stages, chemical marking of otoliths and bones is a commonly used and well established method (BROTHERS 1990). The first studies of this topic were initiated in the 1960s (BROTHERS 1990). Firstly, strontium chloride was used as an analog of calcium and incorporated in bony fish structures (OPHELL and JUDD 1968, BAGENAL et al. 1973). The otoliths marked by this method were analyzed using atomic mass spectroscopy and atomic absorption spectroscopy. The second, more popular method of juvenile stage mass marking was based on the use of fluorochromes (BROTHERS 1990). These compounds form chelation complexes with calcium ions and are embedded in the skeletal structures of fish (bones and otoliths). In this case, the presence of the mark (i.e. illuminating calcium-fluorochrome complexes) can be confirmed by observing these structures under ultraviolet light (BEVERANDER and GOSS 1962, THOMAS et al. 1995). Commonly used chemical markers

are tetracycline group antibiotics (i.e. tetracycline, tetracycline hydrochloride (TC), oxytetracycline (OTC), and oxytetracycline hydrochloride) and calcein (BABALUK and CRAIG 1990, THOMAS et al. 1995, STAŃCZAK et al. 2015). There are four techniques for fluorochrome application: intraperitoneal, intramuscular, intravenous or subcutaneous injections (BEVELANDER and GOSS 1962, BABALUK and CRAIG 1990); spraying dye onto the external surface of fish bodies (PITCHERA and KENNEDY 1977, LESKELÄ et al. 2004); immersing fish in a dye solution (HETTLER 1984, BAER and RÖSCH 2008); and finally feeding fish for several days with artificial or live feed supplemented with the fluorochrome (THOMAS et al. 1995, STAŃCZAK et al. 2015).

Fluorochromes are widely applied in aquaculture today. Besides their applicability in marking procedures, tetracycline and its derivatives are also used as antibacterial drugs (SCHNICK et al. 1986). Therefore, labelling protocols should take into account species specificity, because an overdose of some fluorochromes may have unfavorable and ultimately lethal effects on the fish (HETTLER, 1984, TSUKAMOTO 1985). Therefore, it is necessary to adjust the dose that would enable the most effective marking of fish to ensure minimal mortality rates for the fish stock, which is especially significant for endangered/protected or commercially valuable fish species (MACFARLANE and BEAMISH 1987).

Therefore, the goal of this study was to verify the feasibility of using live *A. salina* nauplii stained with either TC or alizarin red S (ARS) for the mass marking of pike *E. lucius* (L.) larvae.

Material and Metods

For our experiment, we used pike larvae 6 days post hatch (DPH), just before the end of yolk sac resorption, that had an average total length of 13.38 ± 0.64 mm and an average body weight of 12.43 ± 1.4 mg. Fish were obtained from controlled reproduction of spawners originating from the Fish Farm "Czarci Jar" near Olsztyn (NE Poland). During experimental rearing, the fish were administered the live feed *A. salina* nauplii (Ocean Nutrition Ltd., USA), incubated following the producer's instructions, and then immersed in one of two fluorescent dyes, either TC at 600 ppm or ARS at 200 ppm (Sigma-Aldrich Ltd.), according to the method published by STAŃCZAK et al. (2015).

The pike larvae were divided into five experimental groups (each experiment was carried out in duplicate). The fish were placed in separate aquaria (100 fish each) with a total volume of ca. 2 dm3 and coupled to a recirculation system. Each experimental group was fed *ad libitum* manually four times a day. Administration of stained nauplii was conducted for 3 or 6 days for both

fluorescent dyes (TC-3 and TC-6 or ARS-3 and ARS-6 groups, respectively). After treatment, the pike larvae were fed exclusively dye-free (pure, plain) nauplii for the next 7 days. The control group (C) was fed only dye-free *A. salina* nauplii. Throughout the experiment, the aquaria were cleaned of food remains and fish waste once a day in the morning before the first feeding.

Survivors of the experimental rearing were counted and 30 larvae per variant were sacrificed with an overdose of anesthetic (MS-222; 5 g dm^{-3}), individually weighed (to the nearest 0.1 mg) and measured (to the nearest 0.01 cm). After measurements were made, larvae were preserved in 70% ethyl alcohol and then otoliths were dissected from each specimen, placed on microscope slides, embedded in Entellan (Sigma-Aldrich Ltd.), and the intensity of the fluorescence TC in a spectrum with a UV wavelengths from 450 to 490 nm; ARS wavelengths from 510 to 560 nm, with a Nikon Eclipse 90i fluorescent microscope equipped with a Lumen 200 UV lamp (Prior Scientific) in order to detect the fluorescent band within the daily increments of the otolith. The identification and evaluation of the mark quality was carried out using a three grade scale from 0 to 2: 0 – no visible mark, 1 – a noticeable mark and 2 – a conspicuous mark. The mark quality was separately graded twice, and the marks were assessed a third time when the two scores were not consistent. In each group, a mean value of the mark assessment for the 30 studied fish was calculated.

Growth parameters and survival rates were compared using one-way ANOVA. The fit of parameters to a normal distribution was tested using Cochran's C test. The data, expressed in percentages, were arcsin-transformed prior to statistical analysis. Significant differences between groups were estimated using a post hoc LSD Fisher test ($p < 0.05$). Analyses were performed using Statistica software (StatSoft).

Results

Marked otoliths were observed in all experimental groups where the pike larvae were fed live *A. salina* nauplii stained with fluorochromes (Table 1). The highest percentage of marked fish (100%) and highest quality of the mark (1.9–2.0) were obtained from the groups TC-3 and TC-6 (Table 1, Figure 1*a*, *b*). The group ARS-3 had the lowest percentage of marked fish (76.7%) and the average quality of the mark was 1.6 (Table 1, Figure 1*c*). In the ARS-6 group, the percentage of marked fish was insignificantly higher (88.6%), as well as the quality of the marks (1.7) – Table 1, Figure 1*d*. No marked fish were found in the control group (*C*) – Figure 1*e*, *f*. During the experiment the survival rate of pike larvae depended on the group and varied between 90.0 and 93.5% of the

initial stocking. At the end of the experiment, the mean total length ranged from 20.8–21.7 mm and the mean weight of the fish ranged from 38.92–40.37 mg (Table 1). The values of final body weight and length of pike larvae did not differ significantly between experimental groups (Table 1).

Table 1

Results of pike (*Esox lucius* L.) larvae experimental rearing and marking used live *Artemia salina* nauplii immersed with tetracycline hydrochloride (TC) or alizarin red S (ARS)

Group	TL [mm]	BW [mg]	Survival [%]	Marked otoliths [%] $n = 60$	Range and (mean value) of marks quality*
TC-3	21.7 ± 1.0	39.22 ± 6.03	93.5 ± 2.1	100.0	1–2 (1.9)
TC-6	20.8 ± 0.9	38.92 ± 5.36	92.5 ± 0.7	100.0	2 (2)
ARS-3	21.0 ± 0.6	40.37 ± 4.78	92.0 ± 2.8	76.7	1–2 (1.6)
ARS-6	21.2 ± 0.8	39.96 ± 5.34	90.0 ± 1.4	88.3	1–2 (1.7)
C	21.0 ± 0.7	40.15 ± 5.25	93.0 ± 1.5	0	0

* marks quality assigned according to adopted three grade scale: 0 – the lack of fluorescent band on otolith (no mark); 1 – the noticeable mark; 2 – conspicuous mark

No significant differences were found among treatments (One-way ANOVA, LSD Fisher post-hoc test, $p > 0.05$).

Discussion

This paper demonstrates a novel and effective method for mass marking of pike larvae by feeding them live *A. salina* nauplii stained with TC or ARS. Until now, most marking procedures of pike eggs or juveniles have involved immersing them in solutions of chemical markers. CZERKIES (1998) successfully marked fertilized embryos by immersing them in ARS at 200 ppm for 4–6 h or by keeping them in a TC bath of 800 ppm for 6 h. In the case of pike larvae, a 3 h bath in a 150–200 ppm ARS solution or in an 800 ppm TC solution was equally effective. Another method of fluorochrome administration was applied by WAHL and STEIN (1987) to muskellunge (hybrid *Esox masquinongy* and *Esox lucius*). They fed the fish fry with pelleted feed saturated with OTC at a dose of 500 mg/kg body weight and achieved a marking success of 80–100%. BABALUK and CRAIG (1990) also marked pike with OTC using intraperitoneal injection at doses from 25–50 mg kg^{-1} body weight which resulted in a 100% marking rate with marks being visible on all analyzed bony structures as early as 24 hours after injection.

RHOTEN et al. (2014) demonstrated that during immersion marking of northern pike with OTC, success was dependent upon the age of the fish subjected to the marking procedure. In the case of 7 DPH larvae, successful

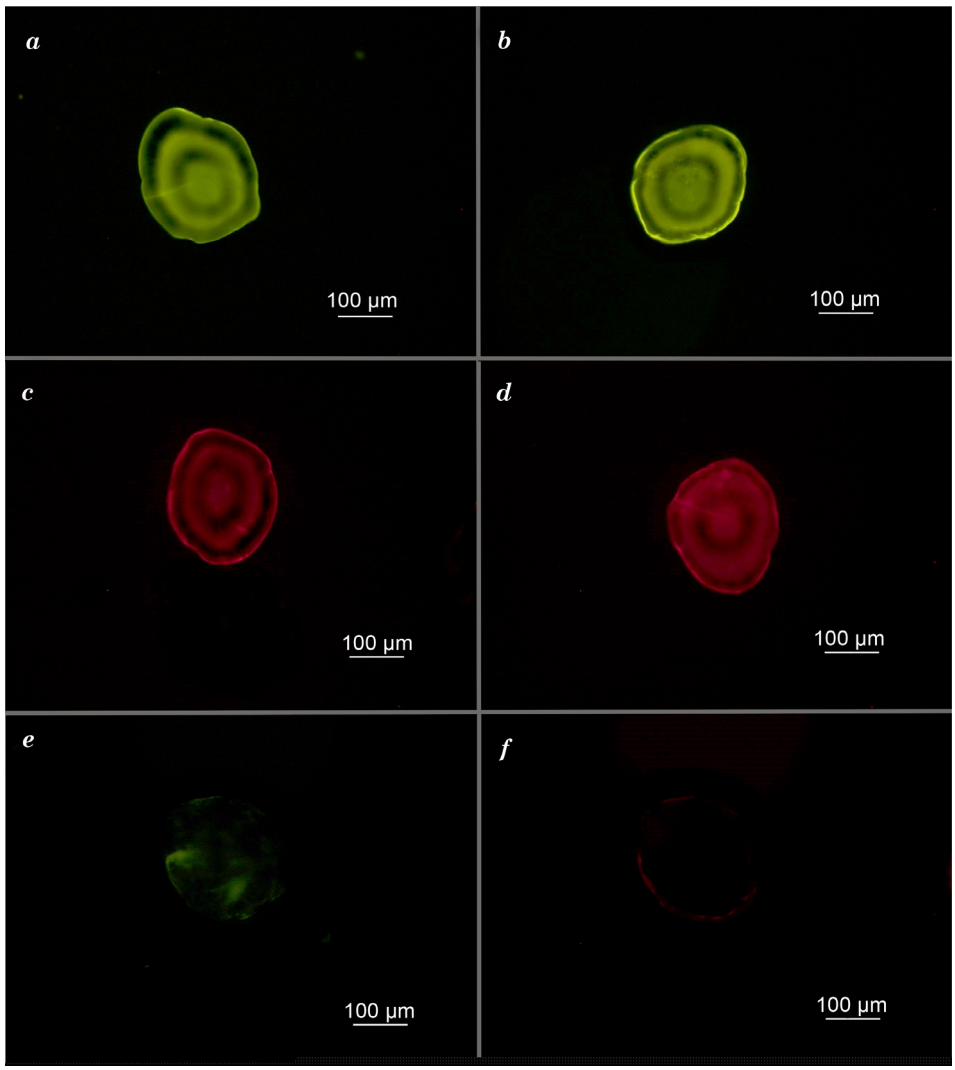

Fig. 1. Otoliths of 18-days old pike larvae after experimental rearing: *a* – group TC-3; *b* – group TC-6; *c* – group ARS-3; *d* – group ARS-6; *e* – control group in the light UV wavelengths from 450 to 490 nm; *f* – control group in the light UV wavelengths from 510 to 560 nm. Bar = 100 µm

marking was noted in only 38% of individuals, whereas in newly hatched larvae (< 1 DPH) the efficiency of marking reached 91% and the quality of the marks was significantly higher. In our study, the marking was conducted using 6 DPH larvae fed live *A. salina* nauplii stained with a derivative of the same fluorochrome. Results were very satisfactory as the marking effectiveness reached 100% when the fish were fed the stained nauplii for both 3 and 6 days.

The described technique of pike larvae mass marking *via* feeding with stained *A. salina* nauplii is much easier to carry out in hatchery conditions, is less expensive as it requires significantly smaller amounts of dyes and is significantly safer for the fish compared to immersion methods. In the case of fluorochrome administration to a fish body using immersion, the marking effectiveness is determined mainly by the physicochemical properties of water. Most of the marker application procedures significantly lower the pH of the water, which reduces the rate of fish survival (HETTLER 1984, TSUKAMOTO 1985). DABROWSKI and TSUKAMOTO (1986) reported a lower efficiency from the immersion method and the formation of a narrower daily growth ridge after using OTC to mark otoliths of peled (*Coregonus peled* L.) larvae reared in water with a temperature of 7.5°C as compared to those reared at 16.8°C. HARRISON and HEIDINGER (1998) concluded that poorly visible marks develop when fish are starved before and after the marking procedure. Additionally, as stated by MEYER et al. (2012), the immersion marking method may induce not only rapid/acute outcomes, but also chronic (sublethal) effects that could result in growth inhibition or increased mortality of the fish.

Our feeding method transfer of fluorochromes eliminates such physiological barriers. The marking of a comparable amount of pike larvae with this method requires several times less dye. This result is important economically and also important for the quality of natural environments by minimizing the effects of water contamination and reducing post-production sludge. In addition, application of the feeding method for marking ensures that the theoretically adopted dose of fluorochrome will not be exceeded.

Many reports demonstrate that the quality of marks is affected by fish size, dye concentration and the length of time to which a fish body is exposed to the fluorochrome (PARTRIDGE et al. 2009). However, higher concentrations of dyes may contribute to increased mortality rates of marked fish (UNFER and PINTER 2013). The methods of pike larvae mass marking described in this paper had no negative impact on the survival or growth of fish (weight/total length). Similarly positive results were obtained when marking brown trout (*Salmo trutta* L.) (BAER and RÖSCH 2008) or European glass eel (*Anguilla anguilla* L.) (CARAGUEL et al. 2014). Thus, we conclude that mass marking with chemical substances (fluorochromes) applied in species specific experimentally determined doses will not have any negative effects on fish growth parameters.

An important aspect of this marking technique is also the retention of marks. According to POCZYCZYŃSKI et al. (2011), the marks obtained for vendace (*Coregonus albula* L.) immersed in 200 ppm ARS were detected without any problems in fish at the age of 3 years or older. In a long-term study on restoration of the autochthonous population of common whitefish (*Coregonus lavaretus* f. *lavaretus* L.) from Lake Łebsko (North Poland), the

fluorochrome marks were identified in fish at the age of 5 years or older (MARTYNIAK et al. 2013). KRUMME and BINGEL (2016) confirmed that the marks obtained on cod (*Gadus morhua* L.) otoliths upon injection of OTC were still clearly visible after 40 years of dark-storage at room temperature.

The results of the present study reveal a need to not only adjust marking techniques by species but also to consider the ontogenic development of fish. In conclusion, feeding 6 DPH pike larvae for 3 days with live nauplii of *A. salina* stained in 600 ppm TC solution is recommended for effective and safe mass marking and this method could become commonly used in fisheries.

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