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THE ANALYSIS OF ENERGY CONSUMPTION IN LINK OF ROTATION: WINTER RYE – POTATO IN SYSTEM OF ORGANIC AND CONVENTIONAL FARMING

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K e y w o r d s: conventional farming, energy consumption, link of rotation, organic farming, potato, winter rye.

A b s t r a c t

The study was conducted in 2008–2010, in north-western Poland, in 10 organic farms and 10 conventional farms. Potato crop of early varieties was in these farms; growing structure every year. In all farms a forecrop for potato was winter rye grown for grain. Cultivation was carried out in similar natural and productive conditions, mainly on soils of class IIIa and IVb.

Productivity of link of rotation: winter rye – potato depends mainly on potato yielding.

In organic farming rye has a definitely higher energy efficiency rate than potato. In conventional farming there was a higher energy efficiency rate in potato growing.

In comparison to conventional system, the organic farming of link of rotation: winter rye – potato is characterized by lower accumulative energy profit (by 50%), a definitely lower energy efficiency rate and higher energy consumption.

The effectiveness of technologies in the organic system should not be limited to a single crop, but considered in a whole production process.

ANALIZA NAKŁADÓW ENERGETYCZNYCH ZMIANOWANIA: ŻYTO OZIME – ZIEMNIAK W SYSTEMIE ROLNICTWA EKOLOGICZNEGO I KONWENCJONALNEGO

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S ł o w a k l u c z o w e: rolnictwo ekologiczne, rolnictwo konwencjonalne, ziemniaki, zmianowanie, zużycie energii, żyto ozime.

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Abstrakt

Badania przeprowadzono w latach 2008–2010 w północno-zachodniej Polsce, w 10 gospodarstwach ekologicznych i 10 gospodarstwach konwencjonalnych. Każdego roku uprawiano ziemniaki odmian wczesnych. Przedplonem było żyto ozime uprawiane na ziarno. Uprawa została przeprowadzona w podobnych warunkach naturalnych i produkcyjnych, głównie na glebach klasy IIIa i IVb. Stwierdzono, że wydajność zmianowania: żyto ozime – ziemniak zależy głównie od plonowania ziemniaków. W ekologicznej uprawie żyto ma zdecydowanie wyższy wskaźnik efektywności energetycznej niż ziemniaki. W rolnictwie konwencjonalnym wyższy wskaźnik efektywności energetycznej stwierdzono w uprawie ziemniaka. W porównaniu z systemem konwencjonalnym rolnictwo ekologiczne w zmianowaniu żyto ozime – ziemniak charakteryzuje się niższym skumulowanym zyskiem energii (o 50%), zdecydowanie niższym wskaźnikiem efektywności energetycznej i większym zużyciem energii.

Introduction

According to many authors, crop production in organic farming system is characterized by lower energy consumption than in a conventional system (LÖTJÖNEN 2003, PETERSEN et al. 1999, PISKIER 2009, REGANOLD et al. 2001). However, as DALGAARD'S research indicates (2003), due to lower crop yields in organic farming systems, energy efficiency is similar to that achieved in conventional system. The report of FOSTER et al. (2006) shows that in the system of organic farming the energy efficiency rate of crops may also have a value less than 1 (below the energy efficiency threshold). Also HILL (2009) indicates that organic farming does not always consumes less energy than conventional farming- it all depends on the employed technology.

The efficiency of agricultural production can be measured in energy consumption. In the organic farming system the energy efficiency rate is highly dependent on the applied technology and the crops obtained (HILL 2009, SŁAWIŃSKI 2010). According to SZEPTYCKI and WÓJCICKI (2003), the efficiency of energy inputs in agriculture is influenced, among others, by: the type of production and its intensity, the level of mechanization, applied technology and production organization. The effectiveness of technology should be considered in the link of rotation which is of particular importance in the system of organic farming, because the effect of organic fertilization and applied agronomic treatments lasts several years. The evaluation of effectiveness cannot be limited to the analysis of individual treatments but it should be considered comprehensively in the full-scale production process. The aim of the study was the analysis of energy consumption in link of rotation: winter rye – potato in system of organic and conventional farming.

Material and Methods

The study was conducted in 2008–2010, in north-western Poland, in 10 organic farms and 10 conventional farms. Potato crop of early varieties was in these farms' growing structure every year. In all farms a forecrop for potato was winter rye grown for grain. Cultivation was carried out in similar natural and productive conditions, mainly on soils of class IIIa and IVb. In the conventional system, pre-sowing rye was fertilized with ammonium phosphate. Additional seeding with nitrogen and potassium fertilizers was taken in the spring. Weeds were fought by a single herbicide spraying. It was used a double foliar nutrition of rye with a solution of urea and magnesium sulphate, and simultaneously anti-hatching regulator, fungicide and insecticide. Pre-sowing potatoes were fertilized with manure at 30 t ha^{-1}. In further growing they were sprayed seven times with chemical substances against weeds, pests and diseases, including foliar nutrition with a solution of urea and magnesium sulfate.

In the ecological system rye in spring was fertilized with manure in an amount of 10 000 l ha^{-1} and basalt powder at 600 kg ha^{-1}. Potatoes were fertilized with manure at 30 t ha^{-1} in the autumn. The cultivation of potatoes consisted of five earthings up (alternately with harrowing) and double spraying with biological insecticide Novodor with the moment of appearing of larvae of Colorado potato beetle.

Farms were self-sufficient in terms of equipment including means of mechanization and did not use the services from outside. Energy consumption of materials and energy value of crop was defined in megajoules (MJ) based on rates of specific energy consumption (WÓJCICKI 2000). Energy efficiency rate (E_{ee}) was calculated from the relation between energy value of crop (P_e w GJ ha^{-1}) and energy expenditures incurred for its formation (N_e w GJ ha^{-1}). The collected data was presented as a 3-year average and was reduced to the area of 1 ha. While estimating the productivity, plant crops were converted into cereal units (*Katalog norm...* 1999).

Results

One of the methods to evaluate crop rotation or its part, is to express the productivity of crops in conventional conversion units, e.g. in cereal units. According to the productivity, organic link of rotation: winter rye – potato is far less productive than the conventional system. While organic farming achieved on average 90 c.u. ha^{-1}, in the conventional system it was 160 c.u. ha^{-1} (Table 1). In both analyzed systems, this value depended mainly on the productivity of potato.

Table 1

Productivity of link of rotation: winter rye – potato in the organic and conventional farm (the average in the years 2008–2010)

Crop	Organic		Conventional	
	winter rye	potato	winter rye	potato
Main crop [t ha^{-1}]	2.15	18.7	3.2	35.4
Secondary crop [t ha^{-1}]	1.89	–	2.1	–
[c.u. ha^{-1}]	24.3	65.5	35.2	123.9
Link of rotation [c.u. ha^{-1}]	89.8		159.1	

In the analyzed production systems, potato growing involves the need to incur more than 2.5 times higher energy expenditures than in the cultivation of rye. Bulb yield, however, carries a large energy potential, that determines the energy productivity of analyzed link of rotation. Comparing energy value of crop to the expenditures incurred on its formation, it was found that in organic farming, rye is characterized by definitely higher energy efficiency rate than potato (Table 2). In the conventional system, potato was characterized by a higher rate of energy efficiency. Rye grown in the organic system and potato in conventional farming had also low (compared to other crops) rate of energy consumption, amounting to 0.44. In both the organic and conventional systems, the cultivation of winter rye was associated with higher (comparing to potato) energy consumption per unit [MJ c.u.$^{-1}$].

Table 2

Selected elements of the energy assessment of potato and winter rye production in the conventional and ecological farm (the average in the years 2008–2010)

Energy beam	Organic		Conventional	
	winter rye	potato	winter rye	potato
Energy expenditures [MJ ha^{-1}]	9 935	25 163	16 120	38 950
Energy value of main and secondary crop [MJ ha^{-1}]	22 743	45 034	32 580	88 500
Accumulative energy profit [MJ ha^{-1}]	12 808	19 871	16 460	49 550
Energy efficiency rate	2.29	1.87	2.02	2.27
Energy consumption rate	0.44	0.56	0.49	0.44
Energy consumption rate per unit [MJ j.z.$^{-1}$]	408.8	384.2	458.0	314.4

Total expenditures of energy, incurred for conventional cultivation of link of rotation: winter rye – potato, were nearly 57% higher than in the organic system. The energy value of obtained crop was definitely higher (78.6%), which has contributed to obtaining over 100% higher accumulative energy profit in conventional system. In organic cultivation of link of rotation: winter rye

– potato energy expenditures incurred to produce 1 cereal unit averaged 390,8 MJ c.u.$^{-1}$ and in the conventional cultivation 346.1 MJ c.u.$^{-1}$. Production of 1 cereal unit in a conventional system required only 88.6% of expenditures incurred in the organic system (Table 3).

Table 3

Selected elements of the energy assessment of link of rotation: winter rye – potato in the organic and conventional farms (the average in the years 2008–2010)

Energy beam	Organic	Conventional	Difference organic=100%
Energy expenditures [MJ ha^{-1}]	35 098	55 070	156.9
Energy value of main and secondary crop [MJ ha^{-1}]	67 777	121 080	178.6
Accumulative energy profit [MJ ha^{-1}]	32 679	66 010	202.0
Energy efficiency rate	1.93	2.20	114.0
Energy consumption rate	0.52	0.45	86.5
Energy consumption rate per unit [MJ j.z.$^{-1}$]	390.8	346.1	88.6

Conclusion

1. Productivity of link of rotation: winter rye – potato depends mainly on potato yielding.

2. In organic farming rye has a definitely higher energy efficiency rate than potato. In conventional farming there was a higher energy efficiency rate in potato growing.

3. In comparison to conventional system, the organic farming of link of rotation: winter rye – potato is characterized by lower accumulative energy profit (by 50%), a definitely lower energy efficiency rate and higher energy consumption.

4. The effectiveness of technologies in the organic system should not be limited to a single crop, but considered in a whole production process.

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THE EFFECT OF INDOLE-3-BUTERIC ACID ON REGENERATION CAPABILITY OF COTYLEDONOUS AND HYPOCOTYLOUS EXPLANTS OF WINTER RAPESEED (*BRASSICA NAPUS* SSP. *OLEIFERA*) DOUBLED HAPLOID LINES

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Key words: auxin, regeneration, doubled haploid, rapeseed, *Brassica napus* ssp. *oleifera*.

Abstract

The division and growth of most types of plant cells kept under *in vitro* culture requires that the medium has an outside source of auxin. Phytohormones stimulate morphology and are essential ingredients of the medium used in the *in vitro* culture. This article presents an experiment whose aim was to evaluate the impact of indole-3-butyric acid (IBA) on the regeneration capability of explants of six doubled haploid lines of rapeseed (*Brassica napus* ssp. *oleifera*) kept under *in vitro* conditions. The cotyledons and hypocotyls were incubated on an MS medium with the addition of 10 mg/l indole-3-butyric acid (IBA).The regeneration assessment was made after 28 days of culture. For all the tested DH lines we observed both substantial genotype differentiation concerning shoot regeneration effectiveness and considerable impact on shoot regeneration of adding the regulator to the medium. The average shoot regeneration effectiveness of the explants incubated on the medium containing auxin was 19.3% with the range of variability falling in between 6.7% and 42.2%.

WPŁYW KWASU INDOLILO-3-MASŁOWEGO NA ZDOLNOŚCI REGENERACYJNE EKSPLANTATÓW LIŚCIENIOWYCH I HYPOKOTYLOWYCH PODWOJONYCH HAPLOIDÓW RZEPAKU OZIMEGO (*BRASSICA NAPUS* SSP. *OLEIFERA*)

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Słowa kluczowe: auksyny, regeneracja, podwojone haploidy, rzepak, *Brassica napus* ssp. *oleifera*.

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Abstrakt

Podział i wzrost większości typów komórek roślinnych utrzymywanych w warunkach kultury *in vitro* wymaga zewnętrznego źródła dopływu auksyn do pożywki. Fitohormony stymulują morfologię i są istotnym składnikiem pożywek stosowanych w kulturach *in vitro*. Celem doświadczenia była ocena wpływu kwasu indolilo-3-masłowego (IBA) na zdolności regeneracyjne eksplantatów z 6 linii podwojonych haploidów rzepaku ozimego (*Brassica napus* ssp. *oleifera*) w kulturze *in vitro*. Eksplantaty liścieniowe i hypokotylowe inkubowano na pożywce MS z dodatkiem 10 mg/l kwasu indolilo-3-masłowego (IBA). Zdolność regeneracyjną oceniono po 28 dniach kultury. Pośród analizowanych linii DH zaobserwowano istotne genotypowe zróżnicowanie dotyczące efektywności regeneracji pędów oraz stwierdzono istotny wpływ dodatku regulatora na regenerację pędów wszystkich testowanych linii DH. Średnia efektywność regeneracji pędów na pożywce zawierającej auksynę wyniosła 19,3% dla zakresu zmienności wynoszącego od 6,7% do 42,2%.

Introduction

Phytohormones are compounds which plants need in order to grow and expand. Auxins are plant hormones which stimulate the growth of cells and take part in the differentiation of the latter (WOŹNY and PRZYBYŁ 2004). The division and growth of most types of plant cells kept under the *in vitro* culture require that the medium has an outside source of auxin (PETRASEK et al. 2002). The type of auxin used in the medium influences the morphogenesis of the culture's explants (HOFMANN et al. 2004). Synthetic auxins are important ingredients of the mediums used in the *in vitro* culture (ŚLESAK et. al. 2005). When added to the medium in appropriately high concentration, they induce formation of callus and adventitious roots (WOŹNY and PRZYBYŁ 2004) and stimulate the process of somatic embryogenesis (VIKRANT and RASHID 2003).

The aim of the experiment was to examine whether adding artificial auxin (indole-3-butyric acid) to the medium had impact on the shoot regeneration process of hypocotylous and cotyledonous explants from six doubled haploid lines of rapeseed kept under *in vitro* conditions.

Materials and Methods

The plant material used in the research included hypocotylous and cotyledonous explants from six doubled haploid lines of winter rapeseed obtained from isolated cultures of microspores from Bor and Wotan varieties (Table 1).

In order to obtain explants, the rapeseed seeds were decontaminated and incubated on the basic MS medium (MURASHIGE and SKOOG 1962) according to the standard *in vitro* sterilization and breeding procedures. The seeds were kept in a breeding room under 16-hours fotoperiod conditions at light source intensity of 3800 lux and temperature of 24 degrees Celsius. After 5 days

Table 1

The origin of the DH lines used in the study

Plant material	DH lines
Bor Cultivar	B-18
	B-21
Wotan Cultivar	W-15
	W-69
	W-70
	W-78

cotyledons and hypocotyls were collected from young seedlings. These explants were incubated on MS medium with the addition of indole-3-butyric acid (IBA) in 10 mg/l concentration. MS medium without the regulator was used as a control. Three explants coming from one seedling including two cotyledons and one hypocotyle were incubated on each plate. The experiment was repeated 3 times with each DH line requiring 15 plates per repetition, i.e. 45 explants. Altogether, 810 explants were collected, out of which 270 were hypocotylous and 540 cotyledonous explants.

The regeneration assessment was made after 28 days of culture. The regeneration effectiveness of each DH line was defined as the ratio of the number of explants regenerating shoots to the total number of explants which were collected, according to the formula:

$$\mathrm{E} = \frac{R}{T} \cdot 100\%,$$

where:
E – stands for regeneration effectiveness,
R – is the number of explants regenerating shoots,
T – is the total number of collected explants (ZANDECKA-DZIUBAK, ŁUCZKIEWICZ 2000).

In order to examine the impact of IBA addition on explants regeneration effectiveness a statistic *t*-student test was carried out with the use of a statistic R platform. The null hypothesis assumed mean identity for both trials, that is no significant differences in shoot regeneration effectiveness between the two examined medium types, while an alternative hypothesis assumed that the means for both trials would differed significantly. The IBA impact on shoot regeneration effectiveness of winter rapeseed DH lines was considered as truly significant when the p value was lower than 0.05.

Results

Among the analyzed DH lines we observed varied impact of the medium type on the shoot regeneration process in the plant parts collected from rapeseed seedlings. Shoot regeneration in explants occurred indirectly via callus and through direct formation of shoots and roots. Callus was formed on each type of explants, yet its formation was limited to the cut parts of plants tissue and, what's more, it spread only in the later stages of culture. The formation of callus and roots was observed mainly in the basal part of hypocotylous explants while the apical end of hypocotyl was more likely to form shoots. Only the explants from W-15 line, incubated on the medium containing IBA, did not create callus. Moreover, in the control medium the formation of callus was not observed in hypocotylous explants from B-21 line and on in cotyledonous explants from W-15 line. It is, however, notable that in the control medium callus was created only occasionally (roughly in 17% of explants) while on in the medium containing auxin it was formed in approximately 67% of the incubated explants.

With the exception of the explants from B-18 line, which did not create roots, rhizogenesis occurred in each line of the cotyledonous explants incubated on the control medium, though to a limited extent. In the medium containing IBA acid root regeneration was observed in all explants, except for the mentioned W-15 line, whose explants did not formed roots. Rhizogenesis was observed in approximately 81% of the explants incubated on the medium with the hormone and in 24% of the explants from the control medium.

In comparison, shoot formation occurred in a smaller number of explants. The range of variability of shoot regeneration effectiveness for the medium containing IBA was between 6.7% and 42.2% for the first repetition of the experiment, 6.7% and 37.8% for the second repetition and 6.7% and 40.0% for the third one. The minimum and maximum values for the control medium were 0% and 6.7% for the first repetition, 0% and 8.9% for the second repetition and 0% and 6.7% for the third repetition. The results of shoot regeneration in the control medium and in the medium containing phytohormone for the three repetitions of the experiments are presented in Figure 1 and Figure 2. The average effectiveness of shoot regeneration in the explants growing on the medium with the regulator reached 19.3% and was higher than the average shoot regeneration in the control medium explants. In the latter group, shoot regeneration was observed only for cotyledonous explants. In the medium containing IBA, shoot regeneration in cotyledonous explants occurred in nearly all DH lines. In comparison, the hypocotylous explants that were incubated on the medium containing IBA were regenerating shoots only in 2% of cases. For both types of the medium, the highest shoot regeneration effectiveness was observed for the W78 line.

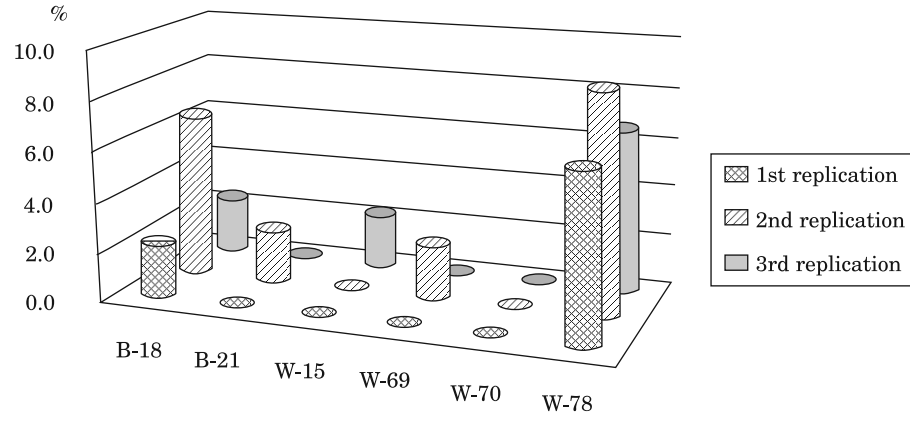

Fig. 1. Shoot regeneration effectiveness [%] of the examined DH winter rapeseed lines in three replications of the experiment in the control medium

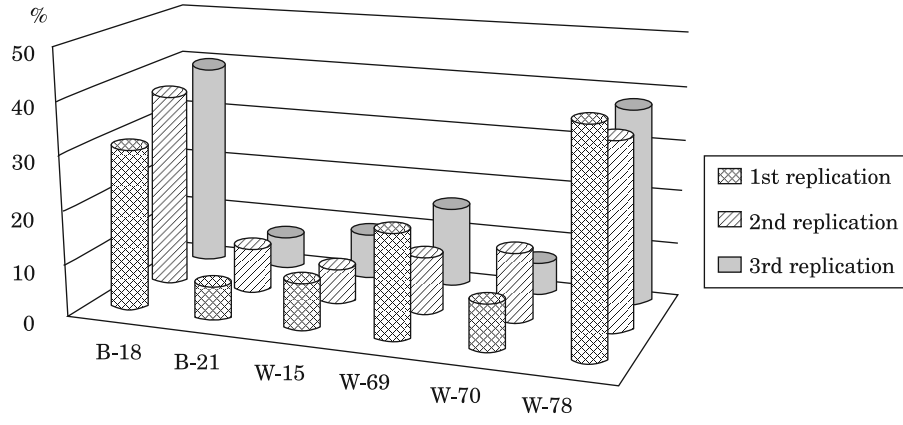

Fig. 2. Shoot regeneration effectiveness [%] of the examined DH winter rapeseed lines in three replications of the experiment in the medium containing IBA phytohormone in 10 mg/l concentration

The student-t test conducted on the samples incubated on the medium with IBA and on the one without it confirmed that IBA had significant impact on shoot regeneration effectiveness in all the tested DH lines. The p-values obtained in the t-student test are presented in Table 2.

Table 2

Impact of IBA regulator on shoot regeneration of DH winter rapeseed lines

The differences in shoot regeneration effectiveness of the explants incubated on the IBA-containing medium as compared to the control medium						
DH lines	B-18	B-21	W-15	W-69	W-70	W-78
p values	0.001*	0.003*	0.002*	0.022*	0.039*	0.001*

* differences significant for $p < 0.05$

Discussion

Regeneration is an important step in the process of obtaining valuable plant material in the *in vitro* culture. As it was mentioned, auxins induce the formation of callus and adventitious roots (WOŹNY and PRZYBYŁ 2004) as well as the process of somatic embryogenesis, provided that they are added to the medium in appropriately high concentration (VIKRANT and RASHID 2003). However, the reaction of explants to the *in vitro* culture conditions may be very different (WOJCIECHOWSKI 1998). Moreover, the type of auxin used in the medium impacts the morphogenesis of the culture (HOFMANN et al. 2004).

In the experiment the formation of callus was observed only in the cut parts of hypocotyls and cotyledons of DH rapeseed lines. An intensive growth occurred only in the later stages of culture, which goes in line with the earlier reports on callus regeneration in *Brassica napus* after the addition of exogenous auxin to the medium (ŚLESAK et al. 2005, ULLAH et al. 2004). The observed formation of roots on the apical side of hypocotyls and of callus and roots on their basal side is also consistent with the results achieved by Ślesak and others in *Brassica napus* cv. Kana.

In the studies conducted by ŚLESAK et al. (2005) and BOGUNIA and PRZYWARA (2000), a 28-day exposition of explants to 2 mg/l 2,4-D exogenous auxin caused inhibition of rhizogenesis and shoot formation. Callus occurred in the majority of the hypocotylous and cotyledonous explants exposed to the regulator, though in very small amounts. For the control medium considerable root regeneration was observed but the callus occurred only from time to time (ŚLESAK et al. 2005). In a study on *Brassica napus* cv. Oscar regeneration (KHAN et al. 2002) higher concentration of 2,4-D regulator suppressed proliferation of callus and adding 8 mg/l of this regulator to the medium resulted in the total absence of callus.

In the current study the presence of callus was observed in both types of explants incubated on the medium containing auxin. Its rare formation was also found in explants incubated on the control medium. These results are consistent with the results obtained by ŚLESAK et al. (2005) and BOGUNIA and

PRZYWARA (2000). In this experiment rhizogenesis was observed in 75% of the explants incubated on the medium with auxin, which does not confirm the results reported by ŚLESAK et al. (2005) and by BOGUNIA and PRZYWARA (2000). In the case of the control medium roots regeneration was definitely less effective than the rhizogenesis observed in the experiments conducted by ŚLESAK et al. (2005). Contrary to the results obtained by previous authors, root regeneration was observed mainly in the cotyledonous explants incubated on the MS medium with IBA. The dissimilarity of the obtained results probably comes from using different types of regulators to initiate shoot regeneration process.

The differences in regeneration effectiveness observed in the experiment may be due to genotype differences of the tested DH lines as the experiment was fully controlled with regard to the temperature, lightening and chemical composition and similar results were obtained in the three replications of the experiment. The obtained results may thus indicate an important role of genotype in determining regeneration capability.

Conclusion

The capability of cotyledonous explants to regenerate is a complex feature which can be affected by genetic and environmental factors. The obtained results confirm that the indole-3-butyric acid can have a positive effect on regeneration capability of rapeseed explants and point to a crucial role of genotype in determining the *in vitro* culture regeneration capability.

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USE OF RIVER RESERVOIRS FOR TOURISM AND RECREATION CASE STUDY: SOLIŃSKIE LAKE IN POLAND

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K e y w o r d s: tourism, recreation, river reservoirs, Solińskie Lake.

A b s t r a c t

The creation of an artificial reservoir usually enhances the tourist attractiveness of the region. Thanks to that, very often tourism around the reservoir develops. The paper deals with the use of artificial reservoirs for tourism and recreation purposes. In the first part, the history of dam construction world-wide and in Poland is briefly discussed, as well as the importance of reservoirs. In the second part, the phenomenon of tourism in the vicinity of one of the most popular reservoirs in Poland, Solinskie Lake, is characterized. Results of studies conducted by the author are also presented.

TURYSTYCZNO-REKREACYJNE WYKORZYSTANIE JEZIOR ZAPOROWYCH NA PRZYKŁADZIE JEZIORA SOLIŃSKIEGO W POLSCE

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S ł o w a k l u c z o w e: turystyka, rekreacja, zbiorniki zaporowe, Jezioro Solińskie.

A b s t r a k t

Powstanie sztucznego zbiornika wodnego najczęściej zwiększa atrakcyjność turystyczną obszaru. Dzięki temu bardzo często następuje rozwój turystyki wokół takiego obiektu. Artykuł dotyczy turystyczno-rekreacyjnego wykorzystywania sztucznych zbiorników wodnych. W pierwszej części krótko omówiono historię budowy zapór wodnych na świecie i w Polsce oraz znaczenie zbiorników. W części drugiej artykułu scharakteryzowano turystykę nad jednym z najpopularniejszych zbiorników wodnych w Polsce – Jeziorem Solińskim. Przedstawiono wyniki badań własnych.

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Introduction

River reservoirs are most often anthropogenic creations which can generally be defined as "water basins of varying size created by constructing a barrier across the river bed or valley, as a result of which its waters become impounded and – which is not necessarily the rule – flow beyond the limits of the naturally formed riverbed" (WIŚNIEWSKI 1998, 79). The majority of reservoirs has been created as a result of constructing an impounding structure across the rived valley – a dam. The history of dams in the world goes back to antiquity, when several dam reservoirs were created in Egypt, Syria, Mesopotamia, Rome, Persia, Babylon, Greece and Anatolia (GŁODEK 1985). The oldest dam reservoir in the world was created in 2900 b.c.e. on the Nile; it had 15 m height and ca. 450 m length.

In the Middle Ages in Europe, civilizational regress could be observed also in the case of hydrotechnical engineering. By contrast, it was developing outside Europe, in Japan, India, and Ceylon (Sri Lanka). In China, many water engineering structures were built, too, although the building of dams impounding the water was rather rare. Structures in India and Ceylon had modest height, but significant length. An example is the Padawiya dam in Ceylon with its height of 21 m and its length of 18 km (GŁODEK 1985). Spain was the leading country in the building of dams in the Middle Ages and in modern times. The Spaniards transferred their experiences to their colonies in America (mostly to Mexico). In the 18th and 19th centuries, hydrotechnical engineering flourished in Europe. Even well-developed water routes were being engineered, and technical solutions – carried over to other world regions – were being perfected. The 20th century is the next stage in the development of water engineering, also because of technological progress. The number of dams, together with their size, grew fast.

The goals of dam building and creating reservoirs varied as the time passed. In the beginning, the main goals were irrigation and water supply. The next functions of the dam reservoirs were navigation, flood protection, and then, together with the development of alternative energy sources, energy supply. Because of high investment costs – both economic and environmental – modern reservoirs fulfill several functions. Single-purpose reservoirs are rare. Despite the complexity of the reservoirs, however, most often one function dominates, while the remaining ones are subordinate to it. This is a result of the conflict between some functions: for example, reservoirs used for residential water supply should be very clean, and for that reason their recreational function is excluded.

As a short overview of the development of dam reservoir functions shows, the recreational function of the objects under discussion is relatively "young".

Nowadays, the use of artificial reservoirs for tourism and recreation is common (cf. NEMETH and DAVID 2007); it is often regarded as an alternative for the overloaded and overcrowded seashore regions. As de REPARAZ (1991) remarked, in France, this caused a movement of tourists towards "artificial interior shores". One should also mention that the very creation of a dam reservoir raises the tourist attractiveness of the region and can contribute to the increase of tourist traffic and to the development of tourism in the region (cf. Duda-Gromada et al. 2010). This is caused, above all, by the landscape values created this way, especially in the mountains, where the combination of a lake and mountains is often regarded as very attractive, even unique. Moreover, opportunities occur for the development of tourism forms related to the direct contact with water.

In Poland, small dams were being built in the 19th century, and some of them even earlier. But all the large dams (above 15 m in height) were built in the 20th century. As CHOIŃSKI (2007) notes, in Poland conditions for building large reservoirs are not favorable, which is due above all to low water flow in the rivers, large variations of runoff, as well as disadvantageous natural conditions. There are slightly over 100 larger dam reservoirs, with maximum capacity over 1 million m^3, in Poland (WIŚNIEWSKI 1998). Their total volume is ca. 3.5 km^3, which constitutes 18% of water resources of lakes in Poland, while their total surface area is ca. 500 km^2, that is, almost 18% of the area of Polish lakes (CHOIŃSKI 2007). The spatial distribution of dam reservoirs in Poland, in particular of the large ones, is non-uniform, which seems obvious. One can observe, however, a distinct concentration of reservoirs in the mountains and foothills, and in the Pomeranian Lake District and the Małopolska Upland.

A decided majority of contemporary dam reservoirs in Poland are multi-function lakes. Many are used also for tourism purposes. Their importance for tourism, however, was most often not taken into account during the planning and construction phases. Therefore, in the case of artificial reservoirs in Poland, their tourism function is most often secondary.

Materials and Methods

In the present paper, both secondary and primary sources have been used. The former have been used as a basis for the discussion of general issues related to dam reservoirs, their history and use for tourism and recreation; as well as for a characterization of Solińskie Lake. The latter, on the other hand, allowed to present basic tourism- and recreation-related issues at the reservoir in question. They were supplied by a survey conducted among tourists in the most frequently visited place at Solińskie Lake: the crown of the dam in Solina,

in July of 2006. Two hundred five questionnaires of the survey have been filled out. In parallel with the survey, a field study was also conducted. Its main part consisted of an inventory of the tourist base, conducted in 2007 and 2008. Facilities in three groups have been counted and localized: accommodation, food services, and auxiliary facilities. Hence, the inventory was conducted from the quantitative and spatial points of view, with facilities being marked on a map. The study was a part of a field study conducted for the doctoral dissertation (DUDA-GROMADA 2009a).

Results – case study: Solińskie Lake in Poland

The area under discussion is situated in south-eastern Poland, in the Małopolskie voivodship. Due to the construction of a dam on the San river in the town of Solina, an artificial reservoir – Solińskie Lake – was created, with its characteristic forked shape. One branch, of 26 km length, fills the San river valley, while the other one, of 11.7 km length, the Solinka river valley. In April 1967 the last segment was completed, which caused the closing of the flow and filling of the reservoir. The water layer as measured by the dam grew slowly, reaching 48.8 m above the San river level at the end of May 1968. The dam and reservoir were put into use on 20 July 1968.

The main functions of the reservoir in Solina are:

– hydropower industry – electrical energy production thanks to water retention;

– discharge equalization – raising of minimum discharge;

– flood protection – flood wave reduction;

– water supply;

– recreation – creating conditions for tourism and recreation.

The dam at Solina is the highest dam in Poland, the longest concrete dam, and has the largest total capacity of its concrete bulk. The reservoir created is also the largest in Poland. The original capacity of the lake was 474 million m^3, but as a result of silting by the material brought by the inflow and that originating from the shore abrasion, it decreased to 470 million m^3 (CHUDY 2004). Basic technical parameters of the dam and the reservoir are presented in Table 1.

As mentioned above, the lake has also a recreational function, thus it is used for tourism purposes. SROCZYŃSKI (2006) conducted studies of the attractiveness of the coastal zone of Solińskie Lake. The studies were conducted for the tourism-recreational use, by means of the physionomical method. Taking into account the practical values first, the author divided the shores into:

– not very friendly – narrow and steep;

– friendly – wider, with gentler profile and well-developed beaches.

Table 1

Technical parameters of the dam and reservoir in Solina

Parameter	Value
dam	
Height	81,8 m
Length	646
Volume of concrete bulk	768 thousand m^3
Discharge capacity of spillways at 420 m a.s.l.	1278 m^3 s^{-1}
Discharge capacity of spillways at maximum impoundment	1863 m^3 s^{-1}
reservoir	
Capacity	ca. 470 million m^3
Useful capacity	ca. 300 million m^3
Surface area	ca. 21 km^2
Length (along the former San riverbed)	ca. 25 km
Maximum ordinate of impoundment	420 m a.s.l.
Average depth	ca. 20 m

Source: own study based on CHUDY (2004).

Shores which are most useful for various forms of tourism as well as water and near-water recreation, take up around 15.5% of the shoreline length. Average-friendly shores, accessible with some difficulties when the water level is average and low take up as much as 66% of the shoreline length. Hard to access, but scenic shores – cliff and rocky shores – take up around 5.5% of the shoreline length.

The characteristic features of Solińskie Lake and the technical parameters of the reservoir and dam made the place into a tourist attraction. Thanks to the diversity of its shores, despite of their mostly difficult access, the area doesn't lose its attractiveness, because it preserves its virginal element. Thanks to this, expectations and needs of various tourist groups can be fulfilled: both of those who expect to find a managed place with high-level tourist services, and of those for whom relaxing by the water, far from bustling civilization is of essence.

As the survey conducted among tourists at Solińskie Lake shows, the main reasons for the choice of destination were natural values (Figure 1): proximity of mountains (63.9% of answers), microclimate (45%), variety of flora and fauna (23.8%). Hence, contact with nature is an important reason for a tourist-recreational trip for the respondents arriving to Solińskie Lake (cf. David et al. 2012). Next to natural values, opinions of other people were an important motivation (as much as 33.7% answers). This may indicate, for example, the popularity of spending free time by a lake, or else, a certain kind of fashion or

fad for trips to Solińskie Lake and for a visit to the tallest water dam in Poland (cf. DUDA-GROMADA 2009b). Worth mentioning is also the category "others": the respondents listed mostly natural environmental values, among which the combination of water and mountains (5 answers) and the proximity to the Bieszczady Mountains (3 answers) dominated. The combination of these two important natural assets – water and mountains – is regarded as an important tourist value also in the opinion of the representatives of local authorities (cf. DUDA-GROMADA, DUDEK-MAŃKOWSKA 2008).

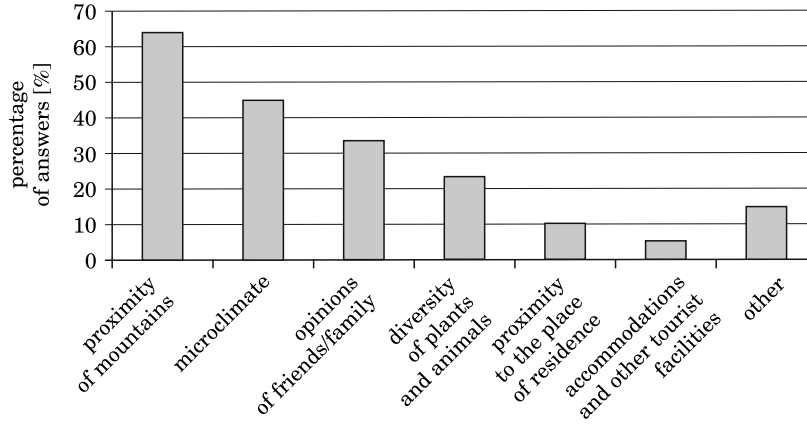

Fig. 1. Tourists' motivation for a trip to Solińskie Lake

The artificial reservoir was also an important motivation for the trip. As the survey shows, for over a half of respondents (52.7%), Solińskie Lake was the main reason for coming here. Hence, an artificial reservoir is an important hydrographical object not only from the point of view of water management, but also from that of tourism. A vast majority of tourists is also of the opinion that Solińskie Lake contributes to the increase of the area's tourist attractiveness.

The time spent during one day near the reservoir is an evidence for the tourists' substantial use of the presence of the lake. As much as 62% of respondents spent at least a few hours by the lake, and around 10% of them declared that they spent almost entire days on tourist-recreational activities near the reservoir. Less than 30% of respondents devoted no more than one hour during a day to water-related recreation.

Tourists were also asked about their way of spending time in the vicinity of Solińskie Lake (Figure 2). Most often, the respondents admired the landscape

(68.6% of answers) and went for walks (54.6%). A large part indicated such forms of tourism and recreation as: sunbathing (38%), bathing (32.2%), or using water recreation equipment (26.8%). Around 16% of answers dealt with visiting water engineering constructions. This is particularly important in the case of the dam in Solina, since – as it was already mentioned – this is the tallest dam in Poland. Studies show that tourists are indeed interested in it. Moreover, since 2006, there has been an opportunity to visit the hydropower plant in Solina and the interior of the dam. Thus, the gamut of tourism and recreational activities has been enriched by elements of industrial (cultural) tourism.

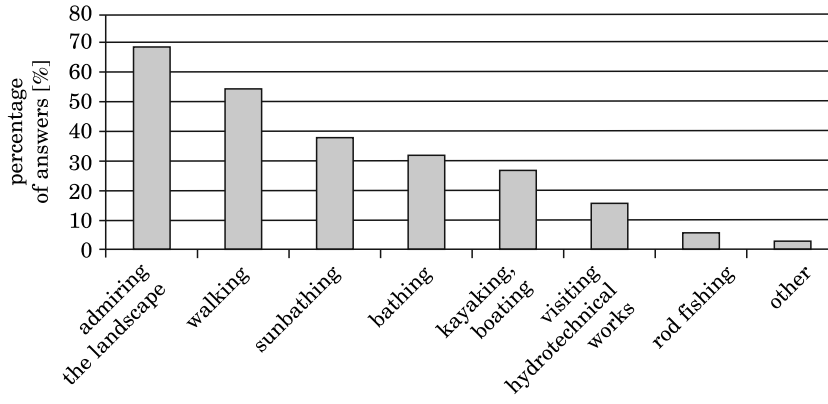

Fig. 2. Tourism and recreational activities by Solińskie Lake

The tourism infrastructure is an important factor attracting tourists. Not only tourism values are a condition for large tourist traffic, but also facilities and services present on the given area, which aim at fulfilling the needs of the recreationers. Among various types of tourism development, accommodation facilities are of particular importance. A characteristic, and very important from the point of view of the potential tourist, feature of the accommodation in the area under discussion is its variety. Accommodation facilities range from hotels with high standards to smaller pensions and campsites. Of particular importance is the large number of agricultural farms and private rooms offered by the locals. This wide range of accommodation caters to various social groups. During the field study, 271 accommodation facilities have been inventoried (Table 2) as well as 32 food facilities with public access (bars, restaurants).

Table 2

Number of accommodation facilities inventoried near Solińskie Lake in 2007

Hotel, pension, inn	12
Sanitarium	6
Recreational center	12
Private accommodation, agritourism farms	227
Campsite	14
Total	271

Auxiliary facilities make it possible for the tourists to take advantage of the values. In the case of near-lake tourism, very important are tourist facilities related to various forms of water tourism. In various parts of the lake, 14 harbors have been inventoried; almost every vacation center has its own harbor and equipment rental at its disposal. Moreover, ships and boats of the Bieszczady fleet navigate regularly Solińskie Lake; they depart from Solina and Polańczyk. But tourism in the wide sense of this word is not limited to the water basin; also other tourist amenities, conducive to other forms of tourism, are important. On the area around Solińskie Lake there are around 15 hiking trails. Also several bicycle trails, of varying length have been marked out, which is important from the point of view of less advanced cyclists. Moreover, there are also equestrian recreation centers. Souvenir kiosks and stands are another important and visible element of tourist development; they are mostly in close proximity of the dam and in Polańczyk. Altogether, 45 such objects have been inventoried.

The distribution of the above-mentioned tourism development facilities around Solińskie Lake is very non-uniform. Field observation suggests that there is a distinct concentration of the facilities close to the reservoir. For this reason, equidistant lines at 500 and 1000 meters from the Solińskie Lake shoreline have been drawn; next, objects located in the given zone have been enumerated. Table 3 presents the number of individual accommodation facilities, depending on the distance from the shoreline. There are 95 facilities within 500 m from the Solińskie Lake shoreline, which constitutes 35%. In the next zone, that is, at the distance between 500 and 1000 m from the shoreline, there are 62 facilities, or 23%. Farthest from the shoreline, beyond 1000 m, 114 facilities have been inventoried, or 43%. One can therefore state that accommodation facilities are concentrated as close to Solińskie Lake as possible.

The food facilities inventoried (bars and restaurant) and auxiliary facilities (souvenir shops and kiosks) is concentrated to an even larger degree in close proximity to the lake. Almost 85% of food facilities and 65% of souvenir shops and stands are located within 500 m from the lake. They cater to tourists and

Table 3

Number of accommodation facilities depending on the distance from the Solińskie Lake shoreline

Distance from the Solińskie Lake coastline	Hotel, pension, inn	Sanitarium	Recreational center	Private accommodation, agritourism farms	Campsite	Total
< 500 m	6	6	11	59	13	95
500–1000 m	4	0	0	58	0	62
> 1000 m	2	0	1	110	1	114
Total	12	6	12	227	14	271

very often are open when tourist traffic is at its most intensive, that is, in July and August, but also on holidays and long weekends (in particular on the May weekend).

Conclusions

Solińskie Lake is an example of an artificial reservoir localized relatively far from larger urban agglomerations. The studies conducted show specific features of tourism around the reservoir under discussion. They are presented briefly in Table 4.

Table 4

Characteristic features of tourism at the lakes under study

Feature	Solińskie Lake
Tourist traffic	most often trips of several days or longer, half of the respondents visited this area for the first time
Tourist motivation	above all, natural environmental values
Main tourism functions	sightseeing, recreation
Tourism infrastructure	well-developed, diversified, large share of agricultural farms

A characteristic feature of tourist development around Solińskie Lake is a diversity of facilities, and therefore of services. On the other hand, an analysis of the development map allowed for a few conclusions. The distribution of facilities comprising the tourism infrastructure is non-uniform. One can distinguish areas which are intensively developed (Polańczyk, Solina, Wolkowyja), and such which are not developed, for various reasons. The calcula-

tions performed indicate a relationship between the intensity of development and the distance from the shoreline. The farther from Solińskie Lake, the fewer tourism-related facilities there are. Therefore, even though studies dealing with the distribution of tourist traffic in the entire gmina are lacking, one can state that the largest number of tourists are in close proximity of the lake. This is an evidence, in author's opinion, of the significant importance of the Solina reservoir for tourism in the region in question.

Using reservoirs for tourism and recreation purposes is common both in Poland and in the entire world. The phenomenon of tourism by Solinskie Lake in Poland, described in the paper, is only one of many examples. The studies conducted show clearly the importance of the reservoir for the development of tourism in the area under study. That's why it is worthwhile to undertake further analyses dealing with tourism in the vicinity of artificial lakes.

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EXPLOITATION AND PROTECTION OF THE POLISH SOUTHERN BALTIC COASTAL ZONE LAKES AND THEIR POTENTIAL FOR RECREATION

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Key words: coastal zone, lake, aquatic vegetation, functions, use, potential for recreation.

Abstract

There are about 30 lakes located on the Polish coast. They vary in terms of use. They are used for many purposes: energetic, fisheries, economic, educational, as receiver surpluses water from the polders, as receiver of social welfare pollutants. Also, some of them are good place for development of specific plant and animal ecosystems. Most of these lakes have very high potential for recreation. Evidence of this include conducting annual sports competitions, setting bike paths around the lakes, creating a pedestrian educational paths, development of technical and social infrastructure.

WYKORZYSTANIE I OCHRONA JEZIOR POLSKIEJ STREFY BRZEGOWEJ POŁUDNIOWEGO BAŁTYKU ORAZ ICH POTENCJAŁ REKREACYJNY

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Abstrakt

Na polskim wybrzeżu zlokalizowanych jest około 30 jezior. Pod względem wykorzystania są one mocno zróżnicowane. Wykorzystuje się je m.in. do celów energetycznych, rybackich, gospodarczych, edukacyjnych, jako odbiornik nadwyżek wód z polderów, jako odbiornik zanieczyszczeń socjalno-bytowych. Niektóre z nich stanowią również dobre miejsce do rozwoju specyficznych ekosystemów roślinnych i zwierzęcych. Większość z tych jezior ma bardzo duży potencjał rekreacyjny. Świadczy o tym m.in. coroczne przeprowadzanie zawodów sportowych, wytyczenie ścieżek rowerowych wokół jezior, stworzenie ścieżek edukacyjnych dla pieszych, rozbudowa infrastruktury technicznej i społecznej.

Introduction

Lakes are an indispensable part of the landscape in which they have an important function. They are vacation spot for people, satisfying their needs of both recreation and esthetic. Influencing local climate, lakes are habitat for numerous species of flora and fauna what is crucial in maintaining biodiversity (ŚWIERK, SZPAKOWSKA 2009). Interactions between human activity, tourism, recreation and natural environment are varied. This results in measurable changes in the human – nature relations, which enter into interactive relationships most strongly (KRZYMOWSKA-KOSTROWICKA 1997).

One of the main components of natural environment where these relationships are very clear are water reservoirs. Often, human or recreation activities carried out too intensively can result in environment degradation and adversely affect the conditions for an optimal relaxation (ZWOLINSKI 1979). Also, improper protection of these objects instead of improving their condition, may negatively impact on their development and persistence in the environment. Among lakes, particular attention should be paid to reservoirs located on the coast. The Southern Baltic Sea area is a place where the primary water relations have evolved under the influence of Scandinavian glacier and its meltwaters, and then underwent a further transformation under the influence of climate change (CIEŚLIŃSKI 2011). Nowadays coastal zone is still characterized by complex water relations, affected by both the water inflow from the land and the proximity to the main drainage base, which is the Baltic Sea, as well as the impact of direct basin and intensive human activity, both in aspect of use and protection. Currently, also local and regional hydrometeorological and hydrographical conditions have strong impact on water conditions.

The main objective of this paper is to determine scope and forms of lakes use on the Polish southern Baltic coastal zone, effects of their use and forms of protection. An additional objective is to investigate their potential for tourism and recreation.

Methods

The main studies were based on fieldwork, including an inventory of the direct catchment of lakes selected to analysis in the hydrographic, quality and economy context. Also during expedition works the water quality measurements were carried out (to determine the physical and chemical composition of water) and morphometric work, including identifying overgrowing areas of each reservoir. In addition to field work the source materials query has been performed. The query was supposed to define the functions and use of each lake. Also, limited to determine concentration levels of indicators such as chlorides, nitrates and phosphates laboratory analysis was performed. The first indicator was intended to determine the degree of sea water's influence on the analyzed lakes, while two others were to specify the impact from the catchment.

Chloride was marked by argentometric titration (Mohr method) nitrate(V) of silver to chromate(VI) of potassium as an index in neutral or slightly alkaline reaction (pH 6.5–10). Nitrates and phosphates were marked by using Photoflex TurbSet photometer and WTW Merck spectrophotometer.

The study area covered the Polish part of the southern Baltic coast between Władysławowo and Wolin Island and also the delta of Vistula. This area is classified as the Coasts of the Southern Baltic (KONDRACKI 2000), which are the hydrographic unit of hydrological conditions different from the rest of the country (CHOIŃSKI 1988).

The following lakes were selected for analysis: Kołczewo, Żółwińskie, Domysławskie, Czajcze, Wisełka, Koprowo (all situated on the Wolin Island), Liwia Łuza, Resko Przymorskie, Jamno, Bukowo, Kopań, Wicko, Modła, Gardno, Smołdzińskie, Dołgie Wielkie, Dołgie Małe, Łebsko, Sarbsko, Kopalińskie, Żarnowieckie (located in the coastal zone of open sea), Pusty Staw, Ptasi Raj, Karaś, Druzno (located in the delta of Vistula). The study period covered the decade of 2001–2011.

Analysis of the lake's recreational values was performed according to the methodology proposed by DEJA (2001). The analysis included morphometric parameters (area, depth), shoreline development index, lake elongation, shores overgrowing, lake surface overgrowing of water vegetation and shores afforestation. Complement to this method was to define the lakes degradation resistance, water quality and tourism activity for each reservoir.

Morphometric lake diversification

Lakes selected for analysis are characterized by morphometric variation (Table 1). As a rule, those reservoirs are shallow, the average depth is 0.6 m (Pusty Staw Lake) to 3.6 m (Wisełka Lake), and the maximum

of 1.7 m (lakes: Liwia Łuza, Smołdzińskie, Dołgie Małe) to 6.3 m (Łebsko Lake). Only in the case of Żarnowieckie Lake its average and maximum depth differs significantly from other reservoirs and amounts to 8.4 m and 19.4 m (Table 1). The area of studied lakes is within the range of 5.6 ha (Kopalińskie) to 7020 ha (Łebsko).

Length of coastline is within the range of 1150 m (Pusty Staw Lake) to 55 400 m (Łebsko Lake), and shoreline development index from 1.13 (Żółwińskie Lake) to 2.44 (Kopalińskie Lake) – Table 1.

Table 1

The main coastal lakes morphometric data

Name of lake	P [ha]	H_{max} [m]	H_{sr} [m]	L [m]	R	A [km^2]
Kołczewo	49.2[6]	4.0	2.2	3675	1.48	1.1
Żółwińskie	41.7[6]	3.0	2.1	2580	1.13	1.0
Domysławskie	43.5[6]	3.1	2.1	3000	1.28	1.3
Czajcze	71.5[6]	4.6	2.9	4970	1.66	1.6
Wisełka	20.0[6]	6.1	3.6	1980	1.25	0.5
Koprowo	486.8[8]	3.1	1.6	9800	1.25	51.1
Liwia Łuza	210.8[8]	1.7	0.9	6500	1.26	160.7
Resko Przymorskie	559.0[1]	2.5	1.3	11700	1.38	315.2
Jamno	2231.5[1]	3.9	1.4	28300	1.69	510.6
Bukowo	1644.0[1]	2.8	1.8	23200	1.57	102.8
Kopań	786.5[1]	3.9	1.9	12350	1.24	38.5
Wicko	1031.0[1]	6.1	2.7	21350	1.85	107.7
Modła	45.1[2]	2.6	1.2	3163	1.76	26.9
Gardno	2337.5[1]	2.6	1.3	23000	1.33	964.4
Smołdzińskie	28.0[2]	1.7	1.3	3075	1.64	0.8
Dołgie Wielkie	131.0[1]	2.9	1.4	6675	1.51	3.2
Dołgie Małe	7.3[1]	1.7	0.7	1197	1.35	0.2
Łebsko	7020.0[1]	6.3	1.6	55400	1.87	1594.0
Sarbsko	614.0[1]	3.2	1.2	15550	1.72	213.3
Kopalińskie	5.6[7]	3.0	1.6	2050	2.44	0.2
Żarnowieckie	1425.0[1]	19.4	8.4	18650	1.39	259.8
Pusty Staw	7.5[3]	3.0	0.6	1150	1.19	0.7
Ptasi Raj	51.8[4]	2.6	1.3	4551	1.78	1.4
Karaś	8.8[4]	2.5	0.7	2145	2.03	1.0
Druzno	1450.0[5]	3.0	1.2	32200	2.39	1084.0

P – area of lakes ([1] – Choiński 2006, [2] – Cieśliński et al. 2009, [3] – Tylmann 2003, [4] – Raśkiewicz, Cieśliński 2007, [5] – Lumberjack 2002 – the area of lake at the water level of 500 cm, [6] – Kubiak, Chojnacki, Tórz 2002, [7] – Cieśliński, Olszewski 2012, [8] – Tórz, Kubiak 2006), H_{max} – maximum depth (Jańczak 1997, Choiński 2006), H_{sr} – average depth (Jańczak, 1997, Choiński 2006), L – coastline length, R – shoreline development.

The lakes catchment area is firmly variable. Among them there are both very small catchment with an area of 0.2–1.6 km^2, and very large catchment with an area over 1,000 km^2. The size of total catchment of studied lakes is within the range of 0.2 km^2 (lakes: Dołgie Małe, Kopalińskie) to 1594.0 km^2 (Łebsko Lake) (Table 1).

Lakes overgrowing

The problem of overgrowing lakes located in the coastal zone of the southern Baltic Sea is fairly important. This includes not only to the coastal zone, where it is possible to grow swamps intensively, but also water depths, where it is possible to grow aquatic vegetation. Mainly reed rushes contribute to lakes overgrowing. They cause the water receding at the rate of 0.3–3.0 m per year (PIOTROWSKA 1997). According to SCHECHTL (1984) rushes cover about 650 ha of Łebsko Lake. According CHOIŃSKI and KANIECKI (2003) rushes in lakes Łebsko and Gardno cover zone width up to several hundred meters, while in terms of area it is covering 9.1% of Łebsko Lake water surface and 4.1% of Gardno Lake. Liwia Łuża Lake reed zone is wide from 5 to 60 m.

Excluding lakes mentioned above, rushes overgrowing problems concerns on most of analyzed lakes. Only in case of lakes located on Wolin Island (except Koprowo Lake) and lakes Żarnowieckie and Pusty Staw reed expansion in their coastal zone is not observed.

Second place of lakes overgrowing is water depths. Most of analyzed lakes have eutrophic waters with near zero transparency, which limits the growth of large submerged vegetation patches. Stronger winds causes intensive mixing of water and sediment resuspension. Permanently submerged in the water depths considerable amount of abioseston effectively limits light diffusion into the water and is an inhibitor of submerged vegetation spread (KRASKA 2003). Łebsko lake water transparency according to KRASKA (1997) varied from 0.4 to 0.7 m and the Gardno Lake from 0.5 to 0.8 m, which results in limited the growth of submerged vegetation. According KRASKA (1997) transparency of Łebsko lake water varied from 0.4 to 0.7 m, and Gardno Lake from 0.5 to 0.8 m, which in consequence limited the growth of submerged vegetation. In the other reservoirs water transparency is less than 1 m. Among the underwater vegetation most noteworthy are *Chara* phytocenoses. *Chara* grow in shallow waters (it is much easier to grow species of vegetation with floating leaves or emergent), in areas less exposed to strong waving, where the water depth varies from 10 to 100 cm (DĄBSKA 1978).

The biggest problem with lakes overgrowing of emergent vegetation relates to following lakes: Modła, Karaś, Gardno, Liwia Łuża, Koprowo. The area

covered by emergent vegetation varies from 1% to 60%. Particular attention should be paid to Druzno Lake with overgrown area covering about 80% of water depths during summer. Fetal lakeside includes not only water route across the lake, which is related to keeping its patency by human activity. Typical reed islands are formed on the surfaces of lakes Modła and Łiwia Łuża. In the case of Łiwia Łuża Lake they cover 20% of the water surface, but in case of Modła Lake even 60%. In turn, this problem does not apply to the lakes without outflow, where generally this occurrence is not observed.

The following table presents estimated values of area overgrown with rushes and emergent vegetation, given in absolute values and percentages (Table 2).

Table 2

Volume of lakes overgrowing with rushes and emergent vegetation

Name of lake	*P* [ha]	Rushes overgrowing [ha]	Rushes overgrowing [%]	Emergent vegetation overgrowing [ha]	Emergent vegetation overgrowing [%]
Kołczewo	49.2	0.0	0.0	0.0	0.0
Żółwińskie	41.7	0.0	0.0	0.0	0.0
Domysławskie	43.5	0.0	0.0	0.0	0.0
Czajcze	71.5	0.0	0.0	0.0	0.0
Wisełka	20.0	0.0	0.0	0.0	0.0
Koprowo	486.8	48.7	10.0	0.0	0.0
Liwia Łuza	210.8	10.5	5.0	42.0	20.0
Resko Przymorskie	559.0	28.0	5.0	11.2	2.0
Jamno	2231.5	223.1	10.0	0.0	0.0
Bukowo	1644.0	82.0	5.0	0.0	0.0
Kopań	786.5	31.0	4.0	0.0	0.0
Wicko	1031.0	30.0	3.0	0.0	0.0
Modła	45.1	0.5	1.0	27.0	60.0
Gardno	2337.5	117.0	5.0	93.0	4.1
Smołdzińskie	28.0	2.8	10.0	0.0	0.0
Dołgie Wielkie	131.0	0.0	0.0	0.0	0.0
Dołgie Małe	7.3	0.0	0.0	0.0	0.0
Łebsko	7020.0	0.0	0.0	632.0	9.1
Sarbsko	614.0	0.0	0.0	0.0	0.0
Kopalińskie	5.6	0.1	2.0	0.4	8.0
Żarnowieckie	1425.0	0.0	0.0	7.2	0.5
Pusty Staw	7.5	0.0	0.0	0.0	0.0
Ptasi Raj	51.8	2.6	5.0	0.0	0.0
Karaś	8.8	2.5	30.0	0.4	5.0
Druzno	1450.0	0.0	0.0	1160.0	80.0

Hydrochemical differentiation of lakes

Coastal lakes are usually characterized by a small average and maximum depth and a large area. These attributes in relation with the location decide of high values of expose index. Expose index, is defined by intensity of the impact of wind on each reservoir. It can be assumed that waters in these lakes are fully mixed by waves. Stratification may occur only in Żarnowieckie Lake. In other lakes In the other lakes, waters are completely mixed (polymictic lakes). Therefore, later in this work evaluation of hydrochemical composition variation was decided to perform only for the surface layer of these lakes.

By analyzing the variability of chloride concentrations (Table 3) it was observed that there are lakes, where the water was characterized by constantly high concentration levels – more than 500 mg Cl^- dm^{-3} (lakes: Koprowo, Ptasi Raj, Karaś, Resko Przymorskie, Łebsko, Bukowo i Gardno). There are also lakes where the chloride concentration increases followed only periodically, usually rapidly. These increases included whole lakes basins, or just their parts (lakes Jamno and Druzno). There are also lakes in which waters high concentrations of these indicators (above 200 mg Cl^- dm^{-3}) were never observed (lakes: Kołczewo, Żółwińskie, Domysławskie, Czajcze, Wisełka, Liwia Łuża, Wicko, Kopań, Modła, Smołdzińskie, Dołgie Wielkie, Dołgie Małe, Sarbsko, Kopalińskie, Żarnowieckie i Pusty Staw).

Analysis of the nitrates(V) and phosphorus(V) revealed that concentrations of both substances in these lakes waters, as well as the variability of concentrations observed over time were very similar. In the case of phosphorus(V) not high mean concentrations of this ion in analyzed lakes waters were observed. The range of variation fluctuated from 0.021 mg PO43 – dm – 3 (Bukowo Lake) to 0.17 mg PO_4^{3-} dm^{-3} (Dołgie Wielkie Lake). Only in the case of lakes Druzno and Liwia Łuża, higher levels of phosphate(V) in relation to the other lakes were observed. In the first case, the average concentration was 0.85 mg PO_4^{3-} dm^{-3}, while the other mg PO_4^{3-} dm^{-3}.

In the case of nitrates(V) high average concentrations of this ion in waters of throughflow lakes were observed. For example, the average concentration of nitrates(V) in the waters of Druzno Lake was 1.74 mg NO_3 dm^{-3}, and in the waters of Kopań Lake 2.39 mg NO_3^- dm^{-3}. In the case of lakes without outflow the nitrate(V) concentrations were low. For example, in the waters of Pusty Staw mean concentrations of nitrates(V) were 0.34 mg NO_3^- dm^{-3}, while in the waters of Żółwińskie Lake 0.31 mg NO_3^- dm^{-3}. The range of variation for all of analyzed lakes varied from 0.18 mg NO_3^- dm^{-3} (Czajcze Lake) to 3.29 mg NO_3^- dm^{-3} (Liwia Łuża Lake).

Considering the variability range of phosphorus(V) concentrations of in waters of all analyzed lakes it can be concluded that it was not very varied

(Table 3). Just in case of some lakes, large variations in their concentrations levels were observed. On the other hand, in the case of nitrate(V), as for the mean values, the high concentrations of this ion was observed in the waters of throughflow lakes (Table 3).

Table 3

Maximum and minimum values for chloride ion, nitrate and phosphate (mg dm^{-3}) in the waters of analyzed lakes

Name of lake	Chloride		Nitrate		Phosphate	
	maximum value	minimum value	maximum value	minimum value	maximum value	minimum value
Kołczewo	14.0	8.0	0.48	0.03	0.210	0.030
Żółwińskie	14.0	10.0	0.56	0.03	0.140	0.010
Domysławskie	13.0	6.0	0.67	0.02	0.110	0.008
Czajcze	13.0	9.0	0.28	0.01	0.180	0.009
Wisełka	15.0	8.0	0.77	0.06	0.150	0.010
Koprowo	780.0	320.0	2.87	0.09	0.190	0.003
Liwia Łuza	160.0	90.0	5.66	0.89	0.689	0.040
Resko Przymorskie	2700.0	1560.0	1.19	0.04	0.160	0.002
Jamno	698.0	70.0	2.31	0.09	1.480	0.008
Bukowo	1188.0	531.0	2.12	0.06	0.122	0.005
Kopań	112.1	85.2	5.72	0.86	0.110	0.010
Wicko	66.6	38.2	5.52	0.92	0.118	0.009
Modła	152.0	26.4	2.54	0.11	0.520	0.020
Gardno	1512.0	13.9	2.18	0.08	0.139	0.001
Smołdzińskie	240.0	81.7	5.38	0.79	0.090	0.010
Dołgie Wielkie	18.9	13.0	0.98	0.02	0.510	0.040
Dołgie Małe	11.9	9.1	0.66	0.01	0.340	0.010
Łebsko	1970.0	409.0	2.00	0.07	0.253	0.001
Sarbsko	87.7	21.0	7.20	0.20	0.080	0.040
Kopalińskie	21.0	11.0	2.12	0.07	0.090	0.040
Żarnowieckie	28.6	8.3	1.11	0.09	0.360	0.006
Pusty Staw	40.9	33.4	0.82	0.06	0.230	0.020
Ptasi Raj	4090.0	2311.0	3.22	0.96	0.139	0.016
Karaś	2703.0	1830.0	4.28	1.13	0.111	0.021
Druzno	652.0	39.0	5.60	0.06	2.000	0.130

The water quality and evaluation of degradation resistance

The Polish southern Baltic coastal lakes analyzed in terms of the physicochemical and biological quality of their waters are characterized by poor quality. There were 8 lakes (32% of all analyzed reservoirs) with NON

class water quality. 10 lakes (40%) are from the scope of III class water quality and 7 lakes (28%) are from II class. There were no lakes with I class waters quality (Table 4).

Table 4

Water quality classes of the Polish southern Baltic coastal lakes

S.n.	Name of lake	Class
1	Kołczewo	II
2	Żółwińskie	II
3	Domysławskie	II
4	Czajcze	II
5	Wisełka	II
6	Koprowo	NON
7	Liwia Łuża	NON
8	Resko Przymorskie	III
9	Jamno	NON
10	Bukowo	III
11	Wicko	NON
12	Kopań	III
13	Modła	NON
14	Gardno	III
15	Dołgie Wielkie	III
16	Dołgie Małe	III
17	Smołdzińskie	III
18	Łebsko	III
19	Sarbsko	III
20	Kopalińskie	II
21	Żarnowieckie	II
22	Pusty Staw	III
23	Ptasi Raj	NON
24	Karaś	NON
25	Druzno	NON

One of the reasons why this happens may be a natural resistance to degradation of these lakes. The natural predisposition to water pollution is possible because of the small depth and strong pressure from the catchment. On the other hand, the influence of the Baltic Sea has a negative impact on water quality (increased salinity). However, the location of lakes in the lower part of the catchment or river basin and the capacity of waters pollutants retention and their accumulation in sediments have negative impact on the

water quality. Based on the obtained results it can be concluded that in most cases the analyzed lakes are low resistant to degradation. 8 lakes were included into the group outside of class, and 10 lakes to the III class group. Only Kopalińskie and Żarnowieckie lakes were included into II class.

Use of lakes

Lakes located in the coastal zone of the southern Baltic were and are used for different purposes. Frequently, these purposes are related to human activities. Kopalińskie Lake in the past, before it was actually a lake, was the site of the peat extraction, used for energy purposes. Human activities initiated its creation, by forming the basin. Nowadays it is a place of human recreation and relaxation. Żarnowieckie Lake is also used by humans. In the 80s of the 20th century, pumped storage Żarnowiec power plant was built. It is located on the south side of Żarnowieckie Lake. It includes, among others artificial lake with an area of 122 ha and a total capacity of 13.6 million m^3, located on the plateau, placed 100 m above the average water level in the lake. Primary, before starting Żarnowiec power plant, hydrological lake attributes indicated stability (DRWAL LANGE 1991), where the annual change in water volume was up to 5%, and the amplitude of water level was up to 50 cm (MIKULSKI 1983). Starting pumped – storage power plant resulted in the transformation of water exchange conditions. Daily variations of water level in the lake after starting the power plant grew to 95 cm. In such conditions, natural annual cycle of water level changes readable before became completely undetectable (MAJEWSKI 1996).

Jamno and Liwia Łuża lakes in the past were used as a place of discharge waters from sewage treatment plant in Koszalin (Jamno Lake) and in Pobierowo (Liwia Łuża Lake). As a result, their waters were heavily polluted and water quality (outside class) evidently indicates that. Currently, despite the lack of waste water discharges into the Jamno Lake it is still heavily polluted. This pollution is a result of large amounts of dirt deposited in the sediments. In periods of re – suspension pollutants are lifted from the bottom of the lake and mixed with water depths, what is the cause of deterioration of its water quality. Another reason for periodic changes in water quality of many lakes can be water discharge from polders surrounding the lakes. Lakes: Koprowo, Liwia Łuża, Resko Przymorskie, Jamno, Bukowo, Wicko, Kopań, Modła, Gardno, Łebsko and Druzno are water receiver from several polders. Druzno Lake is a receiver of water from 12 polders. Waters from polders are characterized by large biogenic compounds pollution, which is the result of pumping by polders water from fields and meadows. This water often very long

stagnate in the fields, before being pumped to each lake. This is confirmed by the results of nitrates and phosphates recorded on a few selected polders of lakes: Łebsko, Gardno and Sarbsko (Table 5).

Table 5

Average concentrations of chemical indicators in waters discharged by selected pumping stations to coastal lakes in the period 2002–2007

Name of lake	Name of pumping station	Nitrates(V) [mg dm^{-3}]	Phosphates(V) [mg dm^{-3}]
Łebsko	Lisia Góra	0.63	0.046
Łebsko	Łokciowe	0.89	0.072
Łebsko	Kluki	0.92	0.081
Gardno	Gardna V–VI	0.91	0.047
Gardno	Gardna VII	0.78	0.033
Sarbsko	Nowęcin	0.55	0.021

Many lakes catchments are used for agricultural purposes. Only a few lakes have forestry catchments (lakes on the Wolin Island and Pusty Staw) or catchment dominated by natural wasteland (lakes Ptasi Raj and Karaś). The result of the impact of agriculture on these objects is their very strong eutrophication. The volume of biogenic compounds loads delivered directly to lakes basins with the surface inflow from the catchment. For example, on average 40.0 tons per month of total nitrogen and 1.6 tons per month of total phosphorus are discharged into the Gardno Lake from the catchment (CIEŚLIŃSKI 2009a). However, 53.5 tons per month of total nitrogen and 2.3 tons per month of total phosphorus are discharged into the Łebsko Lake from the catchment (CIEŚLIŃSKI 2009b). In the case of both lakes in 2008–2010 CIEŚLIŃSKI (2010) observed larger delivery of total nitrogen and total phosphorus into those lakes basins than the results recorded on their outflows into the sea. In the waters of the Łebsko Lake variations of total nitrogen loads were about 30%, and for total phosphorus it was estimated to be nearly 70%. In case of Gardno Lake amount of total nitrogen loads, remaining in the lake basin was estimated at only 1%, and total phosphorus to over 30%.

In principle, all lakes even though to varying degrees, are used for recreation and tourism. This applies not only for tourism around the lake (Pusty Staw Lake) but also recreational activities at the reservoir in the form of the use of lakes for water sports (Jamno Lake, south – west part of the Gardno Lake), sailing and sunbathing (Bukowo Lake). Of course, some reservoirs are poorly used for tourism purposes, which is due to poor technical nd social infrastructure (lakes Wicko and Kopań).

Lakes are also used as a natural retention reservoir, which is often a receiver for water runoff from entire river basin, as it is in the case of lakes Łebsko and Gardno. As a result, they may provide natural protection against flooding to towns such as Łeba and Rowy.

Coastal zone region is characterized by an exceptionally wide variety of habitats, in combination with a complex system of soil – water relations and the characteristics of the local climate, it is a direct base of specificity, as well as the wide variety of its vegetation. For example, flora of Slowinski National Park actually includes 911 species of vascular plants and 165 species of bryophytes. About 300 algal species were also found there, 424 fungi species, and 225 species of lichens. In the zone of the spit there are dune vegetation communities, including two nationally rare and protected species: the Sea holly (*Eryngium maritimum*) and Fragrant Toadflax (*Linaria loeselii).* At the spit, both in the coniferous forests, as well as within moving dunes, in the hollows between the dunes (deflationary basins) a number of unique hygrophilous vegetation communities can be found.

In turn an open area of lakes is place of occurrence hydrophytes with large floating leaves. Halophytic plant communities, rare in Poland, have interesting meadow character.

Of the 450 species of birds observed in Poland in the coastal zone 270 were found among them. There were more than 180 species, which joined the breeding. Other species occurs during migration, they spend the winter here or arrive irregularly. Through the territory of Slowinski National Park, Modła Lake Nature Reserve, lakes Drużno and Ptasi Raj, there goes one of the main routes of spring and autumn birds migrations.

Recreational potential

Most of the lakes in the Polish coastal zone have a very high potential for recreation. This is confirmed by carrying out annual sports competitions such as on the Jamno Lake, demarcation of bicycle paths around the lakes (Liwia Łuża Lake), creation of educational pathways for pedestrians (Łebsko Lake) or technical and social infrastructure expansion (Gardno Lake). Looking at their recreational potential based on natural conditions such as morphometry and overgrowing, it can be concluded that, in principle, these are objects with high recreational value (according to Deja classification of 2001 – II class). Only cases of lakes such as: Smołdzińskie, Dołgie Małe i Pusty Staw, should be included as III class, which are lakes with an average value of recreation (Table 6). Deja classification (2001) does not reflect completely the actual recreational attractiveness of individual reservoirs and limited to a few selected limnological

indicators, without even analyzing tourism in those lakes catchments. Therefore, it was decided to analyze the size of tourism in catchments of individual lakes and then to estimate the number of people staying by the lake in relation to the size of its catchment.

Table 6

Polish coastal zone lakes recreational value according to DEJA classification (2001)

Name of lake	*P*	*h*	*K*	λ	ZSB	ZPJ	ZB	Total
Domysławskie	2	1	2	3	4	4	1	17
Czajcze	2	1	2	3	4	4	1	17
Żółwińskie	2	1	2	3	4	4	1	17
Wisełka	3	1	2	3	4	4	1	17
Kołczewo	1	1	2	3	4	4	1	16
Koprowo	5	0	2	2	4	4	3	20
Liwia Łuża	5	0	2	2	4	3	4	20
Resko Przymorskie	5	0	2	1	4	4	4	20
Jamno	5	0	2	1	4	4	4	20
Bukowo	5	0	2	1	4	4	3	19
Kopań	5	0	2	1	4	4	3	19
Wicko	5	1	2	2	4	4	3	21
Modła	2	0	2	3	4	2	3	16
Gardno	5	0	2	3	4	4	3	21
Smołdzińskie	1	0	2	2	4	4	2	15
Dołgie Wielkie	4	0	2	2	4	4	1	17
Dołgie Małe	1	0	2	2	4	4	1	14
Łebsko	5	0	2	3	4	4	3	21
Sarbsko	5	0	2	2	4	4	4	21
Kopalińskie	1	0	3	3	4	4	1	16
Żarnowieckie	5	2	2	1	4	4	2	20
Pusty Staw	1	0	2	1	4	4	1	13
Ptasi Raj	3	0	2	2	4	4	5	20
Karaś	1	0	3	1	3	4	5	17
Druzno	5	0	3	2	4	1	4	19

P – lake area; *h* – lake depth; *K* – shoreline development index; λ – lake elongation; ZSB – shores overgrowing; ZPJ – lake surface overgrowing of water vegetation; ZB shores afforestation.
Classes of reservoir attractiveness in terms of recreation: to 10 pts – low recreational value of lake – class IV; 10.1 – 15.9 pts – average recreational value of lake – class III; 16.0 – 21.7 pts – high recreational value of lake – class II; 21.8 – 29.0 pts – very high recreational value of lake – I class.

As a result, a very large tourist traffic was observed for lakes located on the Wolin Island and in the Slowinski National Park. Also, lakes located in the delta of Vistula attracted wide interest. The greatest interest was in the

Druzno Lake (700 000 tourists), while the smallest – in lakes Modła and Kopalińskie (15 000 tourists for each lake). In estimating ratio of the number of tourists visiting one area of the lake catchment area it must be assumed that the results for some part of lakes are too large and should not be taken into account. Due to the lack of actual data for individual lakes, this could not be corrected, and so, in fact, there were tourists from 78.4 (Jamno Lake) to 50 000 (Karaś Lake) per 1 km^2 of catchment. This paper was based on the values for each region.

Conclusions

Reservoirs and their floristic environment have positive impact on holiday makers. The water availability heavily determines their recreational suitability. Due to use of tourism and recreation lakes with clear water and available beaches, which have sandy bottom along the shores are most attractive (ŚWIERK et al., 2003). Large size and forestry in close proximity heavily influence the attractiveness of the reservoir (ŁAPIŃSKA 1998).

The Polish southern Baltic coastal zone lakes definitely stand out in terms of hydrological and hydrographic conditions and water quality from other lakes located inland. Such difference results from the location, but also the interaction of the sea and the lakes catchment at the same time. It is interesting that the sea has the greatest influence on lakes despite the fact that sea affects lakes only periodically (what is noticeable in the size of a water salinity). As a consequence of specific location and impacts of different environments those reservoirs perform different functions and are used by humans for many purposes. They are used for many purposes: energetic, fisheries, economic, educational, as receiver surpluses water from the polders, as receiver of social welfare pollutants, as natural retention reservoir, as a habitat for unique species of flora and fauna etc. At that point it should be considered, if the reservoir can perform so many functions and if that can influence on its attractiveness for recreational purposes. It is known that water quality of many lakes is rather poor (III class water purity and outside class), and due to morphometric conditions resistance to degradation of these lakes is low. Also strong overgrowing of their shores and water depths, and furthermore significant loads of nutrients inflow, does not affect the tourist attractiveness of these lakes. Despite this, based on the calculation of the recreational potential proposed by DEJA (2001) and determining the amount of people staying by the selected lake during the year basically all analyzed lakes must be considered as an attractive place for tourists, with high potential for their use by humans. Another positive aspect for the recreational attractiveness

of discussed lakes is the proximity of the Baltic Sea and the well – developed technical, social and accommodation infrastructure in the towns at their close proximity.

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TOURISM AND RECREATION IN THE ŁĘCZYŃSKO-WŁODAWSKIE LAKE DISTRICT (MIDDLE-EAST POLAND) SURVEY RESULTS

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Key words: leisure, lakes, natural assets, tourist attractiveness.

Abstract

The Łęczyńsko-Włodawskie Lake District is one of the main tourist regions of Eastern Poland. The main form of tourism is here mass tourism, based on the use of lakes' shores. The article presents the results of surveys conducted on a group of 850 people rested on the most attractive lakes of area. The issues were mainly related to motives of arrival, ways of spending time and the assessment of tourist attractiveness of the area and the tourist infrastructure. The results indicate a high appreciation of the natural values of the area by tourists. Tourists perceived both positive and negative impacts of tourism development.

TURYSTYKA I REKREACJA NA POJEZIERZU ŁĘCZYŃSKO-WŁODAWSKIM (POLSKA ŚRODKOWOWSCHODNIA) W ŚWIETLE BADAŃ ANKIETOWYCH

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Słowa kluczowe: wypoczynek, jeziora, walory przyrodnicze, atrakcyjność turystyczna.

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Abstrakt

Pojezierze Łęczyńsko-Włodawskie jest jednym z głównych regionów turystycznych Polski wschodniej. Dominującą formą turystyki jest tutaj turystyka masowa oparta na wykorzystaniu strefy brzegowej jezior. Przedstawiono wyniki badań ankietowych przeprowadzonych na grupie 850 osób wypoczywających nad najatrakcyjnieszymi jeziorami Pojezierza Łęczyńsko-Włodawskiego. Zagadnienia dotyczyły w głównej mierze motywów przyjazdu, sposobów spędzania czasu oraz oceny atrakcyjności turystycznej obszaru i elementów infrastruktury turystycznej. Wykazano wysoką ocenę walorów przyrodniczych badanego obszaru przez turystów, którzy jednocześnie wskazywali pozytywne i negatywne aspekty rozwoju turystyki na tym terenie.

Introduction

Lake districts, alongside coastal and mountain areas, belong to the most important areas for tourism. Natural bodies of water and their shores are a component of the natural environment that is commonly used for tourist purposes. In many parts of the world lakes are an essential element of tourism and recreation as both location for leisure activities, as well as an attraction in their own right (HALL, HÄRKÖNEN 2006). Tourism has great importance and economic impact for people and areas near lakes. Lake tourism is defined as a recreational activity (or activities) that involve travel away from one's place of residence and which have as their host or focus the water environment (MILLER 1990).

One of the most popular tourism destination in mid-eastern Poland is the Łęczyńsko-Włodawskie Lake District (Ł-WLD). This geographical region, is situated in Lublin Province, in area where boundaries of Poland, Belarus and Ukraine meet (Figure 1). Because of its physical and geographical features, the Ł-WLD is part of Polesie, which belongs to eastern Europe (it also includes parts of Belarus and Ukraine). The Polish part of the region is called Western Polesie or Lublin Polesie (CHAŁUBIŃSKA and WILGAT 1954).

The Ł-WLD (covering approximately 1160 km^2) is the only group of lakes in Poland situated beyond the reach of the last glaciation. Existing of the lakes is connected with chalk karst processes. Absolute elevations in the area of the Lake District are around 170 m above sea level and show little variation. There are 67 lakes covering more than 1 hectare and many other water reservoirs of natural and anthropogenic origin (WILGAT et al. 1991, CHMIELEWSKI 2001). The Lake District features mainly small lakes (the biggest one covers 284 ha), their shapes exhibiting little variation and often resembling a circle or oval. The lakes' depths vary, but shallow lakes predominate (only 3 lakes are deeper than 30 meters). An important asset of the Lake District is its high level of afforestation. The average afforestation rate for the communes concerned is 31.3% (with the national average of 28.5% and the Lublin Province average of 22.4%); in some communes, the afforestation rate exceeds 40%.

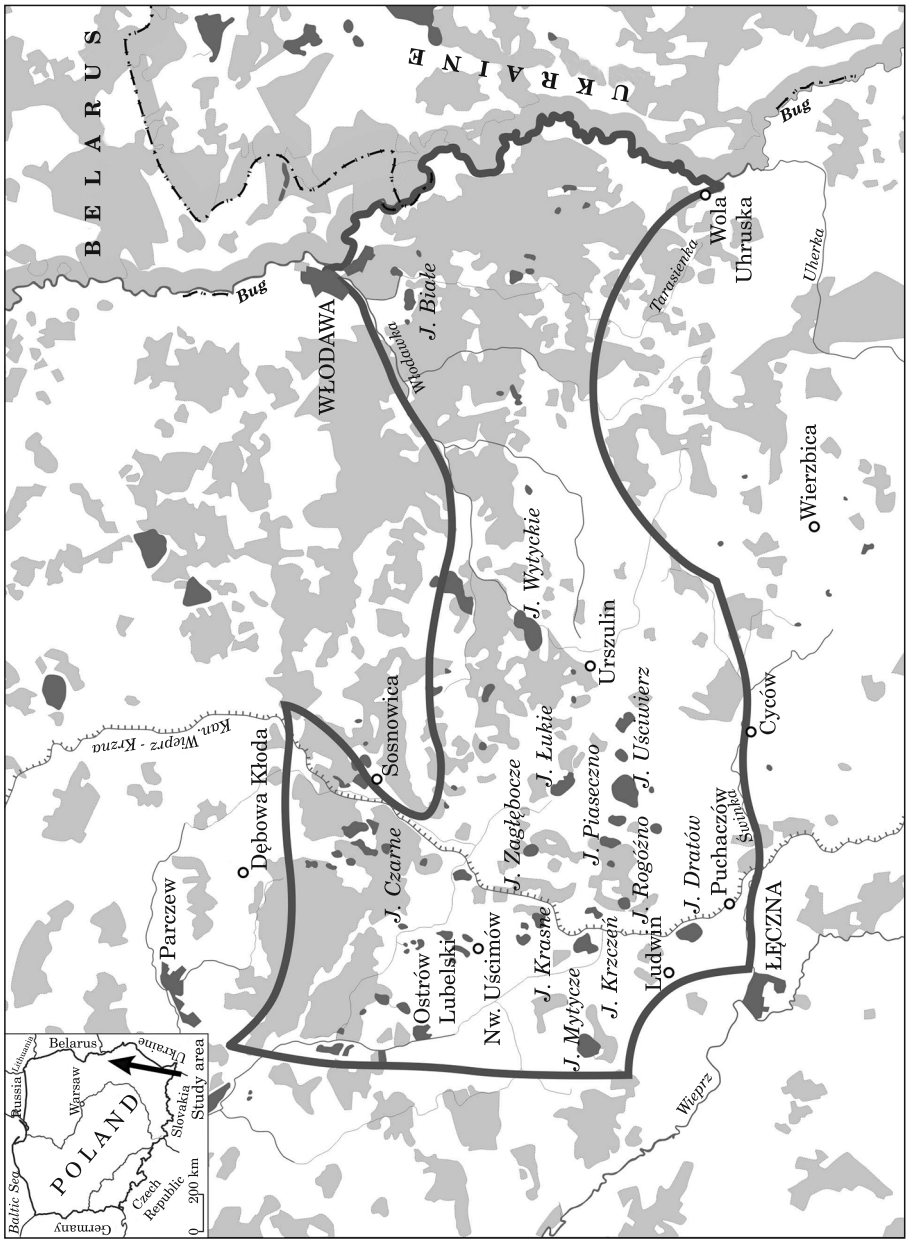

Fig. 1. Localisation of Łęczyńsko-Włodawskie Lake District

Despite numerous land improvement works connected with the construction of the Wieprz-Krzna Canal and starting the exploitation of hard coal deposits, the Ł-WLD has retained its natural, landscape and scientific attractiveness. The most valuable fragments are protected within the Poleski National Park which is the part of UNESCO Biosphere Reserve West Polesie and belongs to the NATURA 2000 project.

Poleski National Park was the first National Park in Poland to be established with the aim to protect peatbog and swamp areas. The Park encompasses a unique territory, which is a miniature of tundra at its extreme south-west European location. Poleski National Park is unique because of the presence of a large number of plants typical to the northern climatic zone as well as the Atlantic zone. One of the most interesting animals in the Park is the mud turtle – the Park's population of this animal is one of the largest in Europe. The Park protects the most precious parts of Polesie Lubelskie, including lakes and floodplains, as well as swamps and peatbogs, which survived in a relatively unaltered shape (*Polski Park Narodowy*. 2002).

Those mentioned above natural assets have determined the development of forms of touristic movement in this region. On the one hand, in area of Ł-WLD there are almost inaccessible lakes under various forms of environmental protection (eutrophic and hyper eutrophic lakes – often they are in the process of turning into a swampy area or a peatbog); on the other hand, there are lakes with sandy bottom and beaches (mesotrophic lakes, e.g. Białe Lake which has I class of water quality – "water for human consumption"). The latter environment has completely different use, typical for lakelands: all kinds of water activity, including diving and fishing.

The impact of tourism on lake environment is a function of the type of activity being engaged in, the number of people engaged and the nature of lake environment itself (HALL, HÄRKÖNEN 2006). Lakes represent resource-based tourist attractions, demanding high levels of management and coordination between users (COOPER 2006). One of the group of stakeholders are tourists and that was the reason for undertaking research on characteristics, preferences and expectations of the Ł-WLD tourists.

The main aim of article is to present the characteristics of tourism at Łęczyńsko-Włodawskie Lake District with special emphasis on the tourist attractiveness, and the tourists' perceptions of tourism development in the region.

Materials and Methods

Analysis of tourist movement in the Ł-WLD indicates that the most popular form of tourism is a leisure/recreational tourism, mostly on the lakes. The scale and intensity of the phenomenon is related to the attractiveness of the lakes and surrounding areas. Tourist movement in both one day and longer (weekend, 1–2 weeks) focuses primarily on the most attractive lakes and lakes with tourist infrastructure.

The tourist attractiveness of Ł-WLD is mainly influenced by the presence of lakes and the type of vegetation. Lakes considered as attractive for recreation, should be characterized by the good water accessibility and proper land use of the shore zone. An important form of land cover for tourism is forest, which has important recreational and aesthetic values and improves environmental conditions (bioclimate). Large part of ecotourism experience and the recreational landscapes depends on the maintenance of forest land, and forests are crucial pockets of biodiversity conservation. Forests are part of the countryside that visitors enjoy, sometimes are the purpose of visit and other times just the setting for recreational activities (FONT and TRIBE 2000).

Therefore into consideration were taken: lakes area, maximum depth, type of bottom, accessibility to water, type of surrounding environment, transport accessibility (Table 1).

Parametes of Łeczyńsko-Włodawskie lakes attractiveness rating Table 1

Parameters	Scoring				
	0	1	2	3	4
Lakes area	–	up to 50 ha	50–100 ha	above 100 ha	–
Maximum depth	up to 5.0 m	5.1–10.0 m	10.1–20 m	20.1–30 m	above 30.1 m
Type of bottom	muddy	sandy	–	–	–
Transport accessibility	lack or week	medium	good	–	–
Accessibility to water	lack	medium	good	–	–
Type of surrounding environment	swamps, fields	meadows	forests	–	–

Scoring method was used – above parameters were divided into classes which were accordingly scored. Attractiveness ratings were made for 53 lakes (the study omitted lakes, which was not possible to determine all the parameters – e.g. depth). On the basis of the above criteria and total points achieved, analysed lakes was divided into three groups of tourist attractiveness:

I – less attractive lakes (1–4 pts.) – 24 lakes,
II – medium attractive lake (5–8 pts.) – 23 lakes
III – very attractive lakes (9–13 pts.) – 6 lakes.

The most attractive – six classified in the third group – have been lakes: Bialskie, Rogóźno, Zagłębocze, Krasne, Piaseczno and Białe. These are large lakes, belonging to the deepest in the area with good transport accessibility. Around this lakes there are many objects of tourist infrastructure: holiday resorts, bungalows and summer houses.

In surroundings of four most attractive lakes (Białe, Zagłębocze, Bialskie, Piaseczno) a survey was carried out in the summer months in 2005–2006. The methodology used to gather information about tourism included structured interviews with tourists. Total number of 850 questionnaires were collected.

Results and Discussion

Surveyed tourists were strongly dominated by Poles. Only two persons were from abroad: one person (participant of the excursion) came from Lutsk (Ukraine) and one from Ireland (Polish woman living in Dublin). The other 848 respondents lived in Poland. Polish visitors came from 14 provinces with the exception of Lubuskie Province and Warmia-Masuria Province (Table 2, Figure 2). They represented 158 towns (including 67 – 42.4% – from the Lublin Province), located in 90 counties.

Table 2

Place of living of respondents by province

Province	Number of respondents	In %
Lublin	587	69.2
Mazovia	149	17.6
Podkarpacie	48	5.7
Małopolska	18	2.1
Silesia	16	1.9
Świętokrzyskie	7	0.8
Lower Silesia	6	0.7
Łódź	4	0.5
Podlasie	4	0.5
Pomerania	3	0.4
Opole	2	0.2
West Pomerania	2	0.2
Kujawy-Pomerania	1	0.1
Wielkopolska	1	0.1
Suma	848	100.0

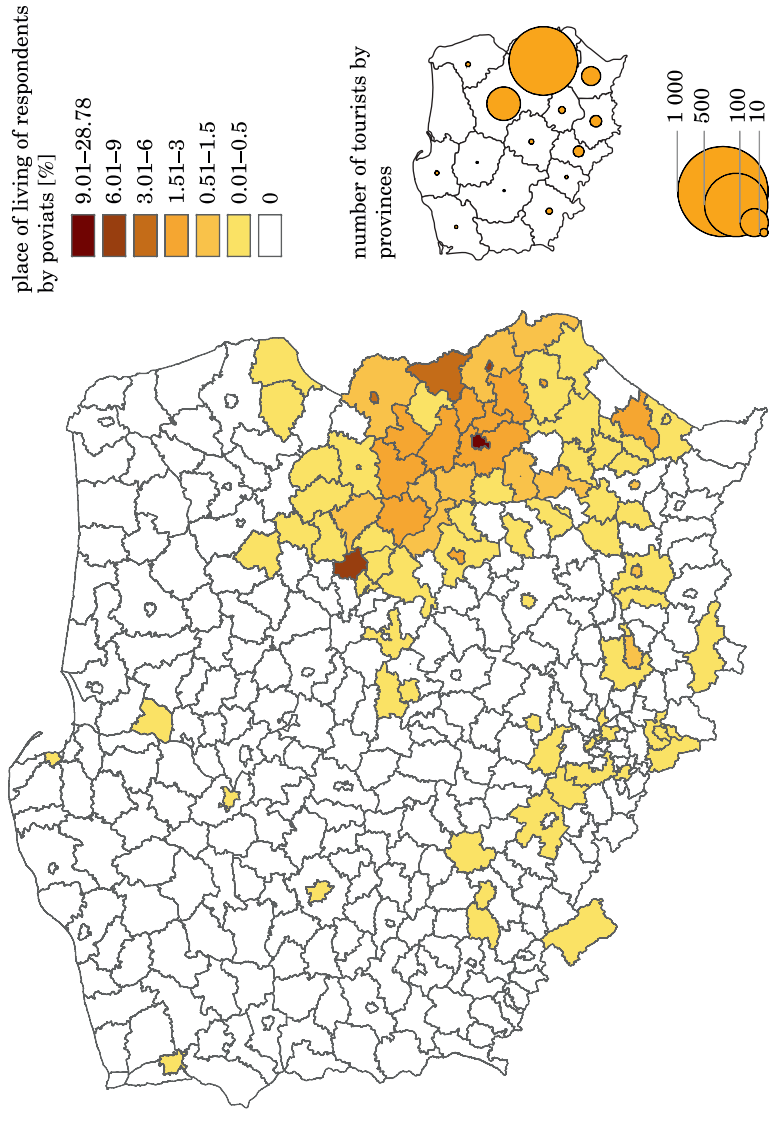

Fig. 2. Place of living of respondents rested on Łęczyńsko-Włodawskie Lake District (survey results)

The largest group of tourists were residents of Lublin Province – 587 pers. (69.2%) and Mazovia Province – 149 pers. (17.6%). Then a fairly large share of tourists were from Podkarpacie Province – 48 (5.7%), Małopolska Province – 18 (2.1%) and Silesia Province – 16 (1.9%). Tourists from other provinces had a much smaller share – less than 1% (Table 2, Figure 2). Among cities largest tourist representations had: Lublin 242 persons (28.5%) and Chełm 68 (8.0%). When taking into account cities located outside the Lublin Province most tourists came from Warsaw (6.1%), Siedlce (2.7%) and Radom (2.4%) (all situated in Mazovia Province).

The vast majority of respondents (82.6%) rested once again on the Ł-WLD. This group was dominated by people who come here from few years (1–9) – 55.9%. From several years (10–19) come here 27.2% of respondents, and from over 20 years – 16.9%. In the surveyed group there were 13 persons (2.5% of all) who come on Łęczyńsko-Włodawskie Lake District from about 40 to 50 years.

The main motive of arrival, which was usually pointed out by respondents was the possibility of spending a holiday on the waterside – 87.4% of responses. Subsequently, the decision to arrive was determined by the attractiveness of the landscape (22.7%), proximity of residence (22.5%) and ecological values of region (forests) (19.9%) – Figure 3.

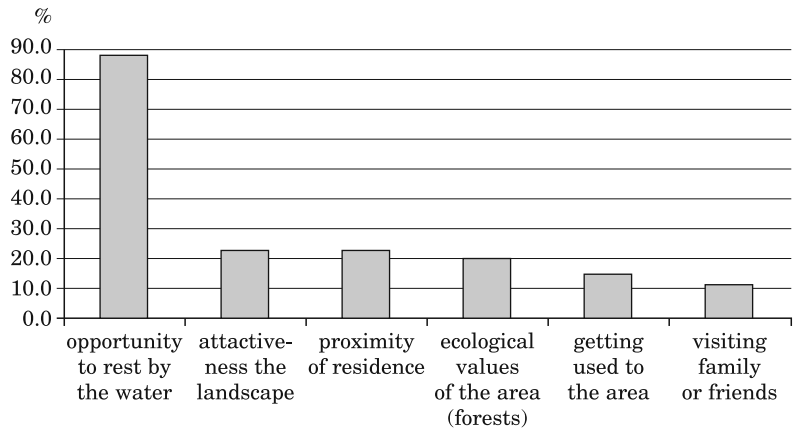

Fig. 3. Main motives of tourists arrival (survey results)

Surveyed tourists usually come on Ł-WLD in July (99.9% of responses) and August (66.8%). The least popular month is November, which indicated only 6 persons (Figure 4).People relaxing in analysed region usually come here once (40.4%) or few times (38.7%) in the year. A large group is the people coming

here frequently (20.9%). Analysis of length of stay indicates that are usually spending here weekends (43.3% of responses), 1–2 weeks (35.0% of responses) and one day (21.7%).

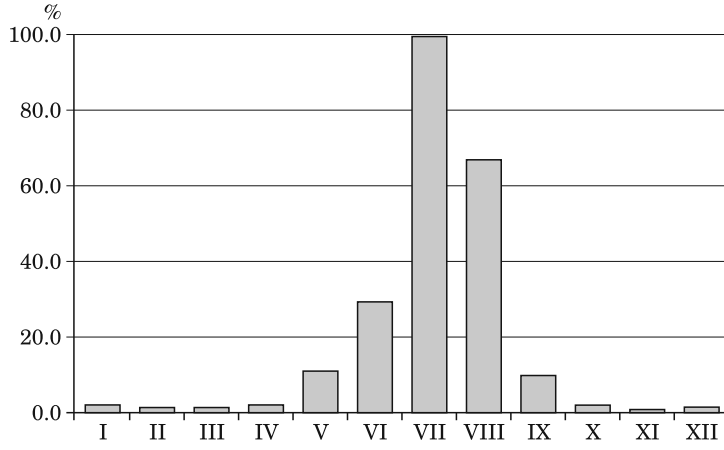

Fig. 4. Seasonality of tourist arrivals (survey results)

The largest group of people using the accommodation on the Ł-WLD are people staying at holiday resorts (39.7%). Almost every fifth surveyed person (18.6%) is staying in a summer house. A large group of people rents private rooms or agrotourism farms – 16.8%, and camping sites – 14.8% (Figure 5).

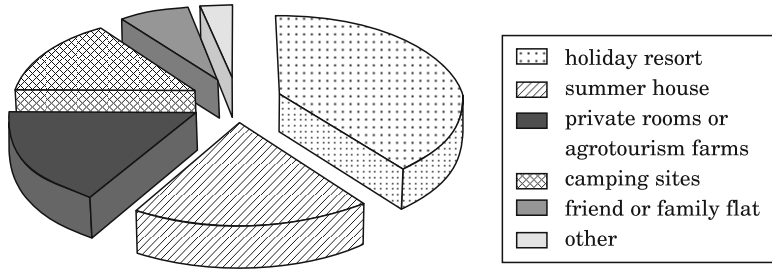

Fig. 5. Accommodation used by respondents (survey results)

Respondents were also asked about how they spend free time during staying at lakes. Approximately 95% of respondents indicated that they mainly rest on the water. About 25% said they spending time in places of entertainment, and walking around nearest surroundings. Nearly 19% of respondents in their spare time enjoys sports (especially cycling and water sports). Only about 7.5% of responses is sightseeing.

The vast majority of tourists (96.5%) estimated the Ł-WLD as an attractive area, in which 59.4% as "rather attractive" and 37.1% – "very attractive". The smallest percentage of indications – 0.1%, pointed out that it is "unattractive" (Figure 6).

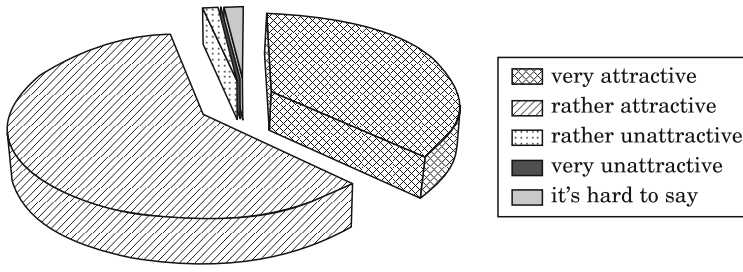

Fig. 6. Rating of tourist attractiveness of Łęczyńsko-Włodawskie Lake District by tourists (survey results)

According to the respondents the attractiveness of the analysed area is largely determined by the presence of lakes (96.3% of responses), forests (30.5%) and opportunity to practicing water sports (22.9%) (Figure 7).

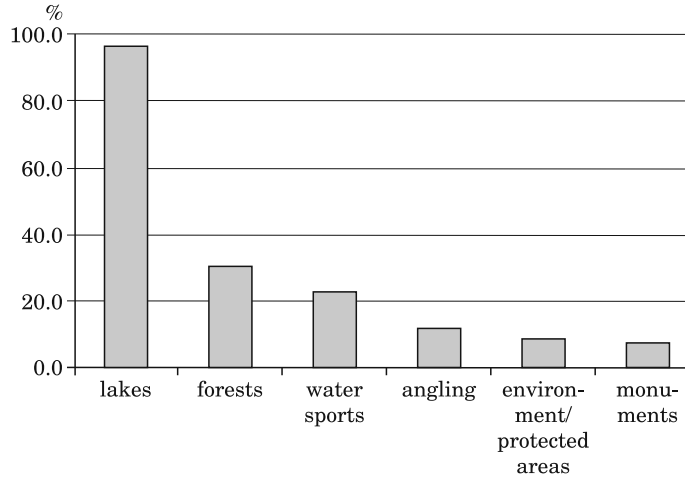

Fig. 7. Elements that determine tourist attractiveness of the region (survey results)

Surveyed tourists were also asked to assess, on a scale from 1 – very bad to 5 – very good, existing tourist infrastructure. Highest rated was catering facilities – 55.9% rated it "good" and 22.6% "very good". The lowest ranked

element of tourist infrastructure transport accessibility – possibility to travel to and around the region. Over 15% of respondents rated it "bad" (11.5%) and "very bad" (3.8%) – Figure 8.

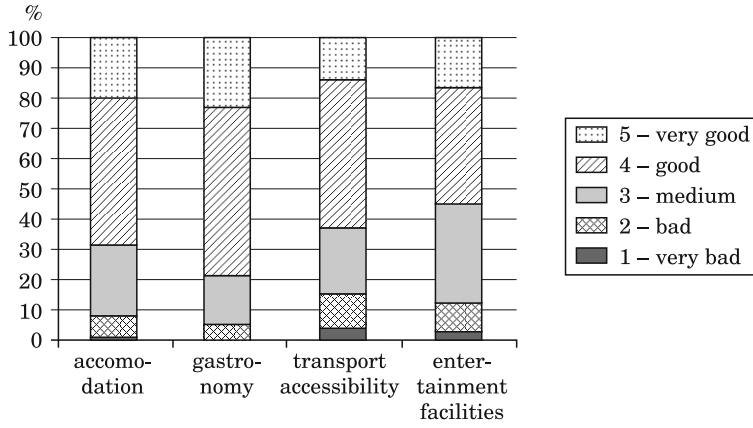

Fig. 8. Assessment of tourist infrastructure (survey results)

In the next question respondents were asked to identify the weaknesses of the tourist infrastructure of the area. The largest group of people pointed to the insufficient number of hiking trails and bicycle paths, and at too low standard of accommodation (respectively 36.9% and 33.7%). Respondents also negatively evaluated the existing transport connections (28.2%), and indicated the lack (or small number) of water equipment rental (22.1%).

Most of changes proposed to increase tourist attractiveness of area involved the expansion or improvement of existing sports and entertainment infrastructure (including sports fields, water slides, playgrounds, water equipment rental) (19.2%). A large group of respondents (15.8%) also indicated the need for greater attention to cleanliness (including setting rubbish bins near the beach). Moreover beaches and piers on the lakes of respondents should be fixed or created (15.0%). Many people also points out the need to raise the standard of existing accommodation (10.5%) and catering (6.7%). Including the elements of the sport and entertainment infrastructure a particular emphasis was on tourist trails (mostly cycling), or rather lack of them – 4.4% response. Among the less numerous, but important, responses, element of lack of promotion and information folders appeared.

Conclusions

In tourism development it is important to know opinions of people who are coming in "our" region. Their "likes" and "dislikes" can decide if they will come here again, and will take friends together. That's why it's valid to take into consideration their propositions of changes.

Analysis of tourist movement in the Łęczyńsko-Włodawskie Lake District indicates that the most popular form of tourism is leisure/recreational tourism, mostly in the lakes. The scale and intensity of the phenomenon is related to the attractiveness of the lakes and surrounding areas, the main role is played by forests. Tourist traffic in both one day and longer (weekend, 1–2 weeks) focuses primarily on the most attractive and urbanized lakes (Białe, Zagłębocze, Bialskie, Piaseczno). A popular and highly developed form of recreation is fishing. Analysis of tourists indicated that the Łęczyńsko-Włodawskie Lake District is a supraregional destination area – also for people coming from outside the Lublin Province.

But we should remember that lakes are significant tourism destinations in their own right and as such demand careful management and planning not only to retain their physical integrity, but also to ensure the quality of the experience of visitors (COOPER 2006). In the case of Łęczyńsko-Włodawskie Lake District tourist are delighted with natural values of the region, but they have quite numerous critical remarks on tourist infrastructure. And one of the major problems of tourism development in the Łęczyńsko-Włodawskie Lake District is excessive concentration of tourist infrastructure objects in some areas. Surroundings of some lakes (e.g. Białe Lake, Bialskie Lake) are overloaded, which reduces the quality of recreation in their neighbourhood. Local authorities and entrepreneur should take it into account.

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VISUAL WATER CLARITY AND LIGHT PENETRATION IN SOME RECREATIONALLY USED LAKES (WESTERN POLAND)*

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Key words: recreation, water clarity, swimming zone, PAR, physical features, turbidity, opalescence.

Abstract

A characteristic of apparent and true depth of illuminated zone in 12 recreationally used lakes of western Poland during the summer was conducted. Depth of photic zone derived from using underwater spherical quantum sensor of photosynthetically active radiation (PAR). The effects of dissolved and suspended optically active substances (chlorophyll *a*, turbidity, total suspended sediment, dissolved substances) on light conditions in the trophic types of lakes were analyzed. Lakes were divided into three trophic states: mesotrophic, eutrophic, and hypereutrophic. Additionally, the content of some optical features of water in zone of swimming versus to lake were analyzed. Turbidity of water was mainly related to the TSS, especially in swimming zone. The large differentiation the depth of illuminated zone within the meso- and eutrophic lakes was noted. The mesotrophic lakes were characterized by greater depth of PAR than lakes of higher trophy. In hypereutrophic lakes with high content of chlorophyll and turbidity in the sub-surface layer the disappearance of light was rapidly below the surface.

PRZEZROCZYSTOŚĆ WODY A GŁĘBOKOŚĆ PRZENIKANIA ŚWIATŁA W WYBRANYCH JEZIORACH UŻYTKOWANYCH REKREACYJNIE (POLSKA ZACHODNIA)

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Słowa kluczowe: rekreacja, przezroczystość wody, kąpielisko, promieniowanie słoneczne, właściwości fizyczne, mętność, opalizacja.

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Abstrakt

Przedmiotem badań była ocena pozornego i rzeczywistego zasięgu strefy prześwietlonej w 12 jeziorach Polski zachodniej wykorzystywanych rekreacyjnie. Badania prowadzono w okresie letnim. Pozorny zasięg światła określano za pomocą krążka Secchiego, a rzeczywisty oraz miąższość strefy fotycznej miernikiem kwantowym (LI-1400, LI-COR) z czujnikiem kulistym (LI-193SA). W obrębie typów troficznych jezior (mezotroficzne, eutroficzne, hypereutroficzne) badano wpływ na warunki świetlne substancji optycznie aktywnych rozpuszczonych i zawieszonych w toni wodnej (chlorofil, mętność, zawiesina, materia organiczna). Dodatkowo analizowano zróżnicowanie przestrzenne właściwości optycznych wody w strefach kąpielisk *versus* pelagial jeziora. W obrębie kąpielisk stwierdzono ścisły związek mętności wody z koncentracją zawiesin. W jeziorach mezotroficznych i eutroficznych odnotowano znaczne zróżnicowanie zasięgu strefy prześwietlonej. Rzeczywisty zasięg światła w jeziorach mezotroficznych był zwykle mniejszy, a w eutroficznych większy w porównaniu z pozornym zasięgiem światła obliczanym na podstawie przezroczystości wody. W jeziorach silnie zanieczyszczonych, gdzie obserwowano często masowe zakwity fitoplanktonu, szarozieloną barwę wody, silną mętność i opalizację, zanik światła następował dość płytko pod powierzchnią wody. W takich warunkach rzeczywisty zasięg światła był zdecydowanie większy od pozornego.

Introduction

The behavior of light in water, particularly its attenuation in subsurface layer, has important ecological implication and shape our perception of water quality. This phenomenon is regulated by the composition and concentration of various attenuating constituents, which include water itself, gelbstoff, tripton, phytoplankton (KIRK 1994) and many others substances named formally as turbidity. The assessment of water transparency and cleanliness by persons enjoying recreation on lakes is frequently ambiguous. Some of us easily identify clean water, but in the case of turbid water, the assessment of its cleanliness is varied, often not reflecting the actual degree of pollution of the lake. The observer only sees water in the coastal zone, where its condition is usually very different from that occurring at a larger distance from the shore. Similar problems with organoleptic assessment of water are encountered by state services specifying its usefulness for bathing. The occurrence in one lake of water zones strongly diversified in physical and chemical terms is related to a number of factors, and concerns both lakes (BAJKIEWICZ-GRABOWSKA 1981, PEŁECHATY 2006), and small waterbodies (JONIAK et al. 2007, JONIAK nad KUCZYŃSKA-KIPPEN 2008). The reasons include among others the resuspension of bottom sediments in shallows and shallow lakes (JAMES et al. 2004), the degradation of the shores, and surface runoff (SMAL et al. 2005, FURGAŁA--SELEZNIOW et al. 2012) as well as excessive human pressure, including recreation (KUCZYŃSKA-KIPPEN et al. 2004, SOBCZYŃSKI and JONIAK 2009).

Lakes, as a place for people the psychophysical power regeneration, are thought to be one of the main determinants of nature's attractiveness for man. Human activities can adversely affect both water quality and the shoreline.

Recreational opportunities are a primary reason people choose to live by or visit lakes, and the demand on our water resources is always increasing. That increasing demand also increases the potential for damage to water quality. Assessing and improving leisure-time activities will help preserve water quality for all hydrobionts as well as for our own recreational purposes. Poor water quality can affect recreation in and on the water, degrade natural habitat, and pose a health risk for water contact recreation (DOREVITCH et al. 2012).

As a result of eutrophication and the connected degradation of lake waters the natural optic features of water change, which leads to numerous changes in the environment. A key consequence of this is an acceleration of the primary production and as an effect there is a considerable decrease of penetration the solar radiation, which is mostly absorbed in the shallow sub-surface layer (JONIAK 2009). Water clarity and depth of light penetration have significant effects on recreational water use. Both features are closely related. Suspended particles and algae have the main influence on light penetration in polluted and eutrophicated waters. The use of Secchi depth (SD) to measure water clarity is a very valuable tool in surface water research. SD offers us readings that are directly related to key ecological variables and human perceptions of water quality (BRUVOLD et al. 1975, STEDMAN and HAMMER 2006). However, many authors pointed out that white disk image attenuation does not only depend on water quality but also changes with the nature of the ambient light field. Therefore, Secchi depth is referred to as an apparent optical property (AOP) (TYLER and PREISENDORFER 1962) and might not be an ideal parameter for modeling water clarity. Alternatively, they suggested using inherent optical properties (IOP), such as the beam attenuation coefficient, which describes the extinction of light due to the processes of absorption and scattering (PFANKUCHE et al. 2000). The aim of study was to characterize the influence of turbidity, total suspended solids, optically active substances and algae biomass as chlorophyll *a* affecting of summer water clarity and depth of solar light penetration in recreationally used lakes of western Poland.

Material and Methods

In the Wielkopolska region, approximately 80 lakes and reservoirs are admitted for swimming in the summer season. The study concerned 12 lakes with bathing sites controlled by the State Sanitary Inspection, and those not subject to control, located at recreation resorts. The study lakes were located in the macroregion of the Wielkopolska Lake District (KONDRACKI 2001), in which a thick net of rivers, lakes of various sizes and post-glacial water bodies appear. The research was carried out in the summer season of 2009 and 2010 in lakes

on the Poznańskie Lakeland, Gnieźnieńskie Lakeland and Lubuskie Lakeland. The area of the lakes are different between 9.0 ha to 348.0 ha, and a maximal depth between 6.8 m and 35.2 m (Table 1). Most of the lakes were closed units in the hydrological sense besides throughflow Łódzko-Dymaczewskie Lake (on Samica Stęszewska River), Biezdruchowskie Lake (on Główna River), and Przedwieśnie Lake (on Sadowicka Struga).

Table 1

Morphometrically characteristics of lakes

Lake	Parameter			Lakeland
	area [ha]	max depth [m]	mean depth [m]	
Lipno	9.0	9.5	5.5	Poznańskie
Dębno	25.1	12.0	6.8	
Strzeszyńskie	33.5	17.8	8.4	
Łódzko-Dymaczewskie	119.6	12.0	5.3	
Chrzypskie	304.3	15.0	6.1	
Strykowskie	305.3	7.7	4.5	
Przedwieśnie	13.4	18.3	6.5	Gnieźnieńskie
Biezdruchowskie	48.8	17.7	5.7	
Budzisławskie	153.5	36.7	11.1	
Wilczyńskie	199.3	24.9	7.8	
Lednica	348.0	15.1	7.0	
Solecko	87.5	6.8	4.1	Lubuskie

Both *in situ* and laboratory measurements were made. Sampling and field measurements were conducted in each lake once during summer (June/July) 2009 or 2010 at a pelagic station. Due to the diurnal dynamics of solar height above the horizon the research was undertaken in between 12 a.m. – 2 p.m. The effects of optically active substances on light conditions in the trophic types of lakes were analyzed. For comparing of some physical features of water the samples from watering places were collected (in triplicate). Apparent water transparency use the Secchi disk was analyzed (white, diameter 30 cm). The apparent thickness of the illuminated zone (ATIZ) was calculated after formulae SD·2.

Vertical profiles of photosynthetically active radiation PAR (400–700 nm) were measured with a spherical quantum sensor LI-193SA with LI-1400 Datalogger (LI-COR Corporation, Lincoln, Nebraska, USA). The spherical sensor expands the range of underwater study of light as it enables the measurement of total PAR. The bottom limit of the euphotic zone (Z_{eu}) is the

depth reached by 1.0% of light penetrating the water surface, and dysphotic zone by 0.1%. True depth of illuminated zone (sum of euphotic and dysphotic zone) for photosynthetically active radiation ($TDIZ_{PAR}$) was determined *in situ*. A vertical attenuation coefficient of PAR (K_d) was calculated by regressing log-transformed light with depth (KIRK 1994) for the euphotic zone (K_{dZeu}). Measurements of light were conducted at the weather stable in terms of insolation (cloudless). When cloudiness occurred during the study, the actual PAR value on the water surface was additionally measured (sensor LI-190SA).

Four measurements were made routinely to characterize the features of optical regime: turbidity NTU (nephelometrically, Eutech Instr. TN-100), total suspended solids TSS (after filtration through GF/F filter, gravimetrical method), optically active substances OAS (characterized by beam attenuation coefficient of membrane 0.45 μm filtered water at 380 nm using a Cadas 200 UV-VIS (Dr Lange) spectrophotometer with a 5 cm glass cell against deionised water (SIPELGAS et al. 2003), and chlorophyll *a* concentrations (ISO 10260). Total phosphorus was measured by acid digestion with persulfate (APHA 1998). Lakes were divided into three trophic states (mesotrophic, eutrophic, hypereutrophic) based on total phosphorus, Secchi depth and chlorophyll *a* measurements using the guidelines of CARLSON (1977) and trophy state index (TSI) ranges value of CARLSON and SIMPSON (1996). Statistic calculations (Carlson coefficient correlations) were made with Statistica 8.0 software.

Results and Discussion

The lakes studied were distinguished by moderate trophic status. This was reflected by values of TSI indices, categorising 6 lakes as the mesotrophic (TSI ≤50). Three of the remaining lakes were eutrophic (TSI >50–70), and three were hypereutrophic (TSI >70). The trophic status was mainly influenced by phosphorus, and to a somewhat lesser degree by chlorophyll (Figure 1). According to the suggestion by Carlson (1977), the index based on chlorophyll is dominant, while the remaining ones are auxiliary. The statistical analysis revealed significant influence of chlorophyll on water transparency (r=-0.61, p<0.033, n=12). The lack of correlation the chlorophyll and total phosphorus was also stated, which suggest excess of this nutrient in lakes and lack of limiting effect on phytoplankton biomass (KAJAK 2001).

Apparent water transparency ranged from 0.50 m in hypereutrophic Łódzko-Dymaczewskie Lake to maximal 8.60 m in mesotrophic Budzisławskie Lake. *In situ* measured euphotic zone depth (Z_{eu}) ranged from 1.0 m to 12.4 m, respectively (Table 2). An examination of the photon stream penetration PAR in the water column showed that it was strongly absorbed in the shallow

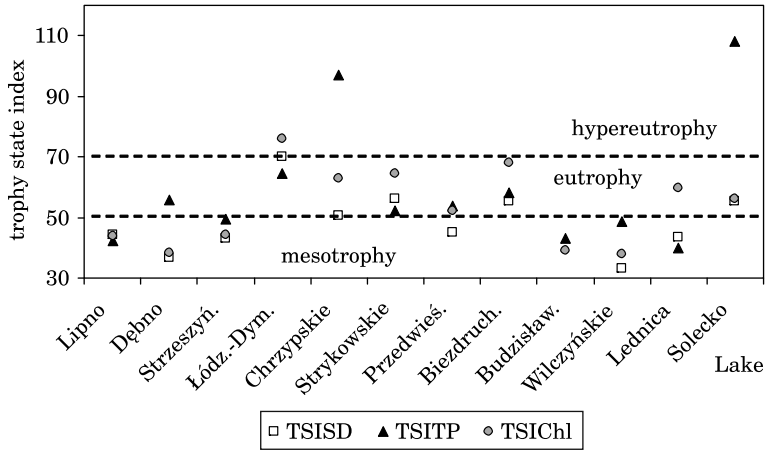

Fig. 1. Trophy state of researched lakes on base of transparency (TSISD), phosphorus (TSITP) and chlorophyll index (TSIChl)

Table 2

Apparent transparency (SD), apparent thickness of illuminated zone (ATIZ), depth of euphotic zone (Z_{eu}), true depth of illuminated zone (TDIZ) and diffuse attenuation coefficients for scalar irradiance in euphotic zone (K_{dZeu}) of study lakes

Lake	Parameter				
	SD [m]	ATIZ [m]	Z_{eu} [m]	TDIZ [m]	K_{dZeu} [m^{-1}]
Lipno	2.95	5.9	4.4	4.5	0.74
Dębno	5.05	10.1	6.5	6.8	0.61
Strzeszyńskie	3.20	6.4	8.0	10.5	0.52
Łódzko-Dymaczewskie	0.50	1.0	1.0	1.6	4.65
Chrzypskie	1.90	3.8	3.4	4.8	1.36
Strykowskie	1.30	2.6	2.2	3.4	1.91
Przedwieśnie	2.80	5.6	5.3	7.0	0.80
Biezdruchowskie	1.40	2.8	3.5	4.7	1.29
Budzisławskie	8.60	17.2	12.4	18.0	0.40
Wilczyńskie	6.35	12.7	9.8	12.7	0.42
Lednica	3.15	6.3	7.4	9.2	0.68
Solecko	1.40	2.8	3.8	4.4	1.12

surface layer of hypereutrophic and eutrophic lakes. This resulted from high water turbidity and algae biomass concentration, and consequently strong light scattering and absorption. The illuminated layer was shallow. In lakes with a lower trophy, the light conditions were clearly better, and TDIZ much higher (Fig. 2). Significant differentiation of the quality of waters in lakes with a lower and higher trophic status was reflected in K_{dZeu} values (Table 2).

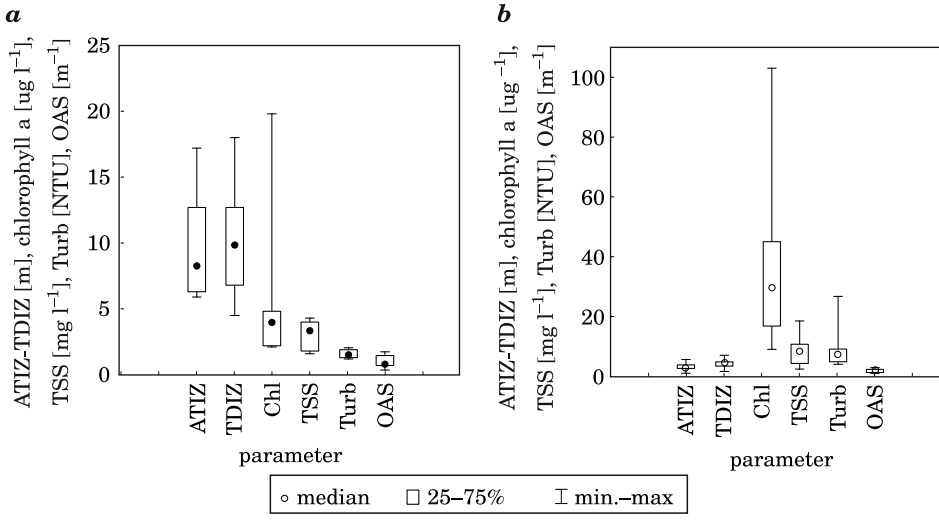

Fig. 2. Apparent and true range of photic zone in relation to concentrations of chlorophyll, TSS, turbidity and optically active substances (median values) in mesotrophic lakes (*a*), and eu- and hypereutrophic lakes (*b*)

In mesotrophic lakes K_{dZeu} showed a low variation (mean 0.56 m^{-1}, std. dev. 0.14 m^{-1}) than in lakes of higher trophy (1.97 m^{-1} and 1.41 m^{-1}, respectively).

Differentiation of the ATIZ and TDIZ in lakes with a high trophy state revealed the underestimation of the true range of the photic zone. The range of light was mean 1.2 m higher than that estimated on basis the Secchi disk visibility. In mesotrophic lakes, the relation was not so unequivocal. In 4 lakes, TDIZ was higher or equal to ATIZ and in lakes Dębno and Lipno it was much lower (Table 2). The feature distinguishing the lakes was the occurrence of shallow-layer turbidity in the zone of limited Secchi visibility, where the turbidity was 4–5 times higher than that in the shallow waters. This type of turbidity results from the accumulation of (mainly dissolved) organic substances (REINART et al. 2003) as well as picoplankton and microorganisms. The barrier limiting light availability in this case are bacterial colloid suspensions or gels released in abundance by plankton and bacteria, frequently forming layers of varied thickness (JONIAK 2009). The excess of organic substances results in the opalescence of water similar to that observed in the deoxygenated near-bottom waters rich in hydrogen sulphide (JONIAK et al. 2010). This type of transformations of physico-chemical conditions of the lake environment directly affects the light conditions, suggesting unfavourable changes in the ecosystem.

The comparison of the content of physical components in the surface water (0–0.5 m) of the pelagial zones and bathing sites revealed much higher concentrations of suspensions and turbidity (Figure 3). Water turbidity at

bathing sites was determined by TSS (r^2=0.92, p<0.000), and to a lesser extent by OAS (r^2=0.64, p<0.002). These relations were also dependent by the character of the material forming the bottom within the bathing site. Mineral coarse-grained sand generated higher suspension concentrations, and fine-grained (till) or organic material – higher OAS values. According to DAVIES-COLLEY and SMITH (2001) suspended particles are the dominant influence on light penetration in most natural waters, except of highly colored waters. In the pelagial, turbidity was exclusively correlated with TSS (r^2=0.87, p<0.000), mainly constituted by chlorophyll (r^2=0.95, p<0.000). This type of relationships with algae biomass is typical for the pelagial of deep non--through-flow lakes with high trophy, where the abioseston occurs in minimum

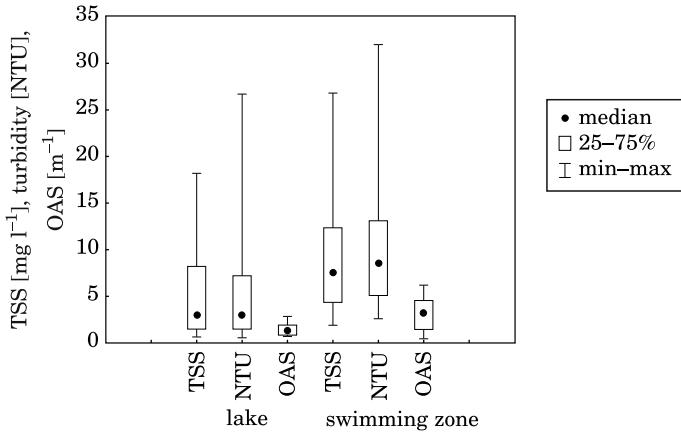

Fig. 3. Differentiation of the concentration of total suspended sediments (TSS), turbidity (NTU) and dissolved optically active substances (OAS) in water of sub-surface layer in pelagial and swimming zone of researched lakes

quantities or not at all. Under low or zero-flow conditions, the finer particles (as phytoplankton) tend to occupy the surface zone of the waterbody, whilst the coarser particles tend to occupy the deeper zone of the waterbody (BILOTTA and BRAZIER 2008). It is worth attention that high correlation of parameters occurred *) in the group of lakes representing varied level of trophic status and **) in the shallow near-surface level considered as an area dangerous for phytoplankton (algae suspended in the water column) due to the penetration by harmful short-wave UV radiation (HÄDER et al. 2007). The occurrence of chlorophyll *a* in the strongly illuminated water layer suggested lack of the harmful influence of UV resulting from absorption by dissolved organic substances (JONIAK 2007). Although, the reduction in light penetration through the water column restricts the periphyton and submersed macrophytes assimilating of energy through photosynthesis this mechanism is not so

important for the planktonic species including surface phytoplankton (GONÇALVES et al. 2011).

High turbidity within bathing sites was mainly generated by suspended solids. The composition of suspension was not analysed. Designing such analyses should consider external factors such as wind which can change both the concentration and composition of suspensions in the daily cycle. If wind blows towards the bathing site, it develops breakers exceeding the impression of turbidity by pushing high amounts of phytoplankton towards the shore and elevating abioseston from the bottom (JAMES et al. 2004). In such conditions, the concentration of suspensions at the shore is unnaturally high, and can have a significant deleterious impact on the physical, chemical, and biological properties of the waterbody (BILOTTA and BRAZIER 2008). The water has a form of a mixture of suspensions, and our impression of water cleanliness is very bad. The organoleptic assessment of the usefulness of water for bathing conducted in such conditions (according to the guidelines of the Minister of Health) often results in closing a bathing site, even in a clean lake, until the moment of explaining whether the visible suspension is a mass cyanobacterial bloom or harmless tripton.

Conclusions

1. Lakes used for recreation include those representing a wide range of water quality – from clean to highly polluted. This results in a high scale of differentiation of optical features of the water and light conditions.

2. Using lakes with phytoplankton blooms, in our climatic conditions usually developed by toxic cyanobacteria, for recreational purposes is potentially dangerous for the health of humans, and particularly children. The concentration of phytoplankton biomass in the shallow surface layer of a lake results in the grey-green colour of water, and its opalescence and turbidity. The true range of PAR in such conditions, however, is higher than that estimated based on Secchi visibility.

3. At bathing sites water turbidity is higher than in the pelagial mainly due to the occurrence of suspensions. The composition of suspensions is not only determined by the migration of matter from the pelagial (horizontal pushing the algae by wind), but mainly by the properties of sediments deposited at the bottom of the bathing site. Fine-grained mineral and organic sediments, natural for majority of lakes, usually increase the impression of water turbidity of people using the lakes and is unreasonably assesed as the effect of water pollution by sewage.

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WATER QUALITY AND PHYTOPLANKTON OF THE RECREATIONAL USED LAKE SŁAWSKIE*

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Key words: nutrients, phytoplankton abundance, recreational lake.

Abstract

The main purpose of this study was to determine the water quality parameters, phytoplankton composition and their seasonal variation in the Lake Sławskie. Samples for water quality analyses were collected once a month in the years 2010–2011. According to physico-chemical parameters the ecological status of the Lake Sławskie was moderate. The lake is characterized by thermal and oxygen stratification within a period of summer. Among mineral forms of nitrogen an ammonium nitrogen dominated. In the case of ammonium nitrogen the maximum concentration reached 3.45 mg N-NH_4 l^{-1} in summer 2010 (near the bottom). In winter and early spring periods the participation of nitrate nitrogen increased. Its maximum concentration was noted in February 2010 (1.58 mg N-NO_3 l^{-1}). Participation of nitrite nitrogen in water was low. The concentrations of dissolved phosphates and total phosphorus reached 0.53 mg P l^{-1} and 0.61 mg P l^{-1} near the bottom layer in the summer 2010, respectively.

The qualitative and quantitative structure of phytoplankton were analyzed. The number of algae ranged from 100 org. ml^{-1} to $23.1 \cdot 10^3$ org. ml^{-1}. Domination of cryptophytes, chrysophytes, diatoms, chlorophytes and dinophytes were noted.

JAKOŚĆ WODY I FITOPLANKTON REKREACYJNIE WYKORZYSTYWANEGO JEZIORA SŁAWSKIEGO

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Słowa kluczowe: związki mineralne, liczebność fitoplanktonu, jezioro rekreacyjne.

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Abstrakt

Celem badań była analiza jakości wody Jeziora Sławskiego na podstawie cech fizyczno-chemicznych, a także określenie składu gatunkowego fitoplanktonu oraz jego zmienności sezonowej. Próbki wody do analiz pobierano co miesiąc w latach 2010–2011. Stan ekologiczny Jeziora Sławskiego określono jako umiarkowany. W okresie letnim Jezioro Sławskie charakteryzowało się dobrze wykształconą stratyfikacją termiczną i tlenową. Analizując udział poszczególnych form azotu mineralnego w wodach badanego jeziora, stwierdzono dominację form azotu amonowego. W okresach letnich odnotowano wzrost jego stężeń, zwłaszcza w strefie naddennej zbiornika, w której wynosiły one do 3,45 mg $N\text{-}NH_4$ l^{-1} w roku 2010. W okresach zimowych i wczesnowiosennych wzrastał udział azotu azotanowego. Jego maksymalną koncentrację stwierdzono w lutym 2010 r. (1,58 mg $N\text{-}NO_3$ l^{-1}). Udział azotu azotanowego w badanym jeziorze był niewielki. Na podstawie analiz ilościowych i jakościowych fitoplanktonu stwierdzono, że liczebność glonów i sinic wynosiła od 100 org. ml^{-1} do $23{,}1 \cdot 10^3$ org. ml^{-1}. W analizowanym okresie stwierdzono dominację kryptofitów, okrzemek, złotowiciowców oraz zielenic i bruzdnic.

Introduction

The Sławskie Lake is the largest lake situated in the area of the Lubuskie Province. This lake is used for recreation and water sports very intensively (International Regatta and Yacht Competitions, Polish Cup Regatta, windsurfing and yachting). The economic development of the city of Sława in the past, particularly the meat industry as well as the rapid development of the tourism, cause the real threat of the sewage inflow and water quality deterioration of the lake. As a result of the enhanced eutrophication process of this lake the strong cyanobacterial blooms were observed. Because of these events, some radical actions were undertaken, targeting on the localization and diversion of untreated sewage from the lake. Because of that the modernization of urban sewage treatment plant in Sława and also diversion of treated sewage from the lake were carried out.

The main aim of this paper was to present the water quality changes as a result of these protection measures of Lake Sławskie.

Materials and Methods

The Lake Sławskie is a gutter, postglacial lake. Its area is 854.67 ha, the maximum depth is 12.3 m and the average depth is 5.2 m. The lake basin runs from the north-west toward south-east, which at the domination of west winds favours the intensive water mixing.

Samples for water quality analyses were collected in the years 2010–2011 (from February to November, once a month) from water column in the deepest part of the lake from the surface and from the depth of 1, 2, 4, 6, 8 and 10 m. Directly in the field the temperature of the water was monitored, the concentration of dissolved oxygen, the conductivity, pH and Secchi disk (SD) visibility

were measured by an instrument WTW 350. In the vertical profile of the lake physico-chemical and biological parameters were analysed, such as concentration of nitrogen (ammonium, nitrite, nitrate, organic nitrogen and total nitrogen) and the phosphorus (dissolved phosphates and total phosphorus). Concentration of chlorophyll-*a* (*Woda i* ścieki. PN-86/C-05560.02) and dry mass of seston (suspended solids) were also measured. All physico-chemical analyses were done according to the Polish Standards (ELBANOWSKA et al. 1999). The qualitative and quantitative composition of phytoplankton was analysed. The phytoplankton samples were collected from the same depth as for chemical analyses and fixed with Lugol's solution. They were analysed under a light microscope, at ×400 magnification. For the quantitative phytoplankton analysis, a Sedgwick-Rafter chamber of 0.67 ml in volume was used. The counting units were cells, colonies, or trichomes.

In both years of research in the summer-time aquatic macrophytes were also explored. Analyses of the arrangement of submerged vegetation were done using the method of transects, localized perpendicularly to the shoreline. They started from the shoreline or from the line of emergent plants and finished at the place of maximal depth at which submerged vegetation occurred. The range of individual plant communities, evaluated on a basis of phytosociological Braun-Blanquet method, was estimated using a special anchor.

Results and Discussion

The lake is characterized by thermal and oxygen stratification within a period of summer. The average water temperature varied from 2.55°C to 21.13°C (July 2010).

Maximum values of water temperature were noted in the summer of the year 2010, when reached 25.9°C in the surface layer. In the following year of research it did not exceed 22.1°C. In remaining months the temperature of water was almost equal in the vertical profile.

The summer oxygen stratification of water of this lake was also observed. In the overdemersal zone the oxygen deficits were noted (Figure 1). In July 2010 the concentration of the dissolved oxygen in water amounted below 2 mg O_2 l^{-1} from the depth of 5 m. In the following year of research the situation rallied and the lowered oxygen layer content appeared only below 7 m in August and October. In the surface layer of water the considerable oxidation were noted, where the oxygenation reached above 198% in first and 150% in the second research year. The highest concentration of dissolved oxygen was noted down in June 2010 at depth of 1 m – 17.18 mg O_2 l^{-1}. In the following year it reached 14.6 mg O_2 l^{-1} in the same layer in October (Figure 1).

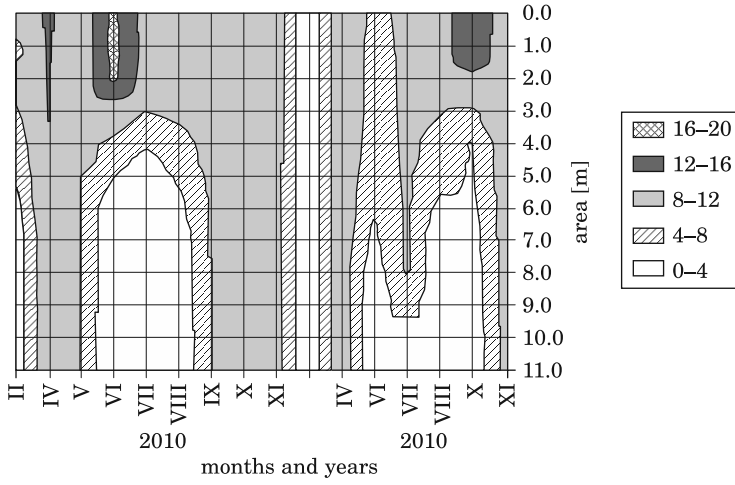

Fig. 1. Changes in the concentration of dissolved oxygen in the water in the vertical profile in the Lake Sławskie in the period of 2010–2011 [mg O_2 l^{-1}]

In the studied period the pH varied from 7.3 to 8.8, maximum values achieving within the period of summer. The conductivity increased in the deepest water layers of the lake, but did not exceed the value of 600 μS cm^{-1}. The water transparency in the Lake Sławskie in analyzed period fluctuated from 1.2 m to 6.4 m. The highest SD value was noted down in winter 2010 and lowest in June 2011. Among mineral forms of nitrogen an ammonium nitrogen dominated. In the case of ammonium nitrogen its concentration reached 3.45 mg $N\text{-}NH_4$ l^{-1} in summer 2010 near the bottom (Figure 2). In the following year, this form of nitrogen concentrations were slightly lower and reached a maximum of 1.9 mg $N\text{-}NH_4$ l^{-1} in November. In winter and early spring periods the participation of nitrate nitrogen increased. Its maximum concentration was found in February 2010, and reached 1.58 mg $N\text{-}NO_3$ l^{-1}. In the summer period (August and September 2010, and in July and August of 2011) the presence of this form of nitrogen was not detected in the water. In the second year of the study a slight decrease in the amount of this form of nitrogen in the water was noted. Participation of nitrite nitrogen was low.

The similar distribution was found in a case of dissolved phosphates and total phosphorus concentrations. They reached 0.53 mg P l^{-1} and 0.61 mg P l^{-1} near the bottom layer in the summer 2010, respectively (Figure 3).

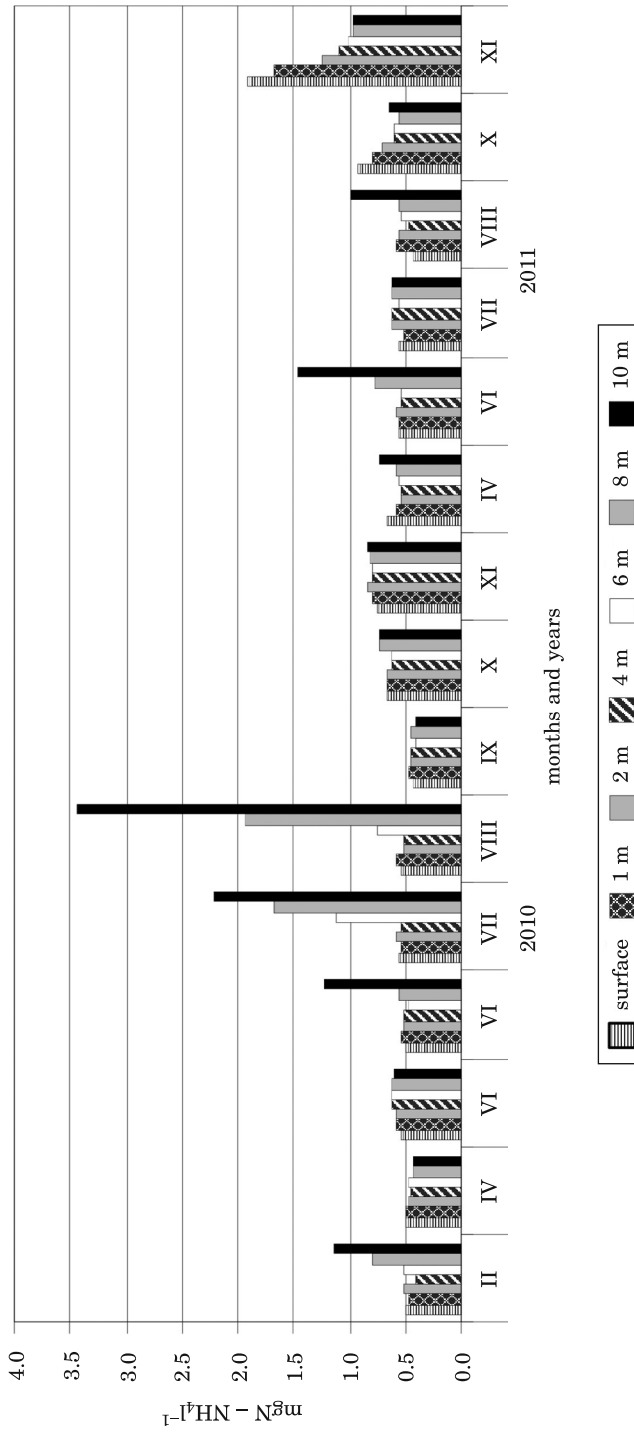

Fig. 2. Ammonium nitrogen concentration in the vertical profile of Lake Sławskie

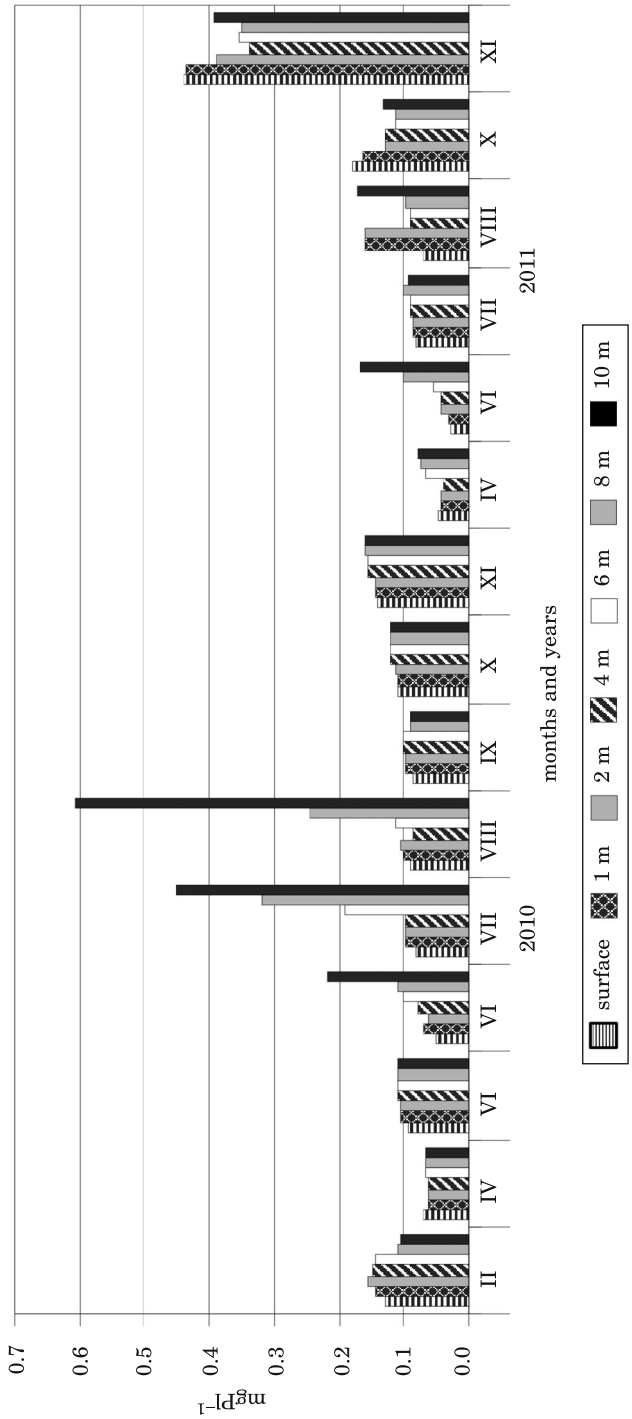

Fig. 3. Changes of the concentration of total phosphorus in the vertical profile of Lake Sławskie during the investigated period

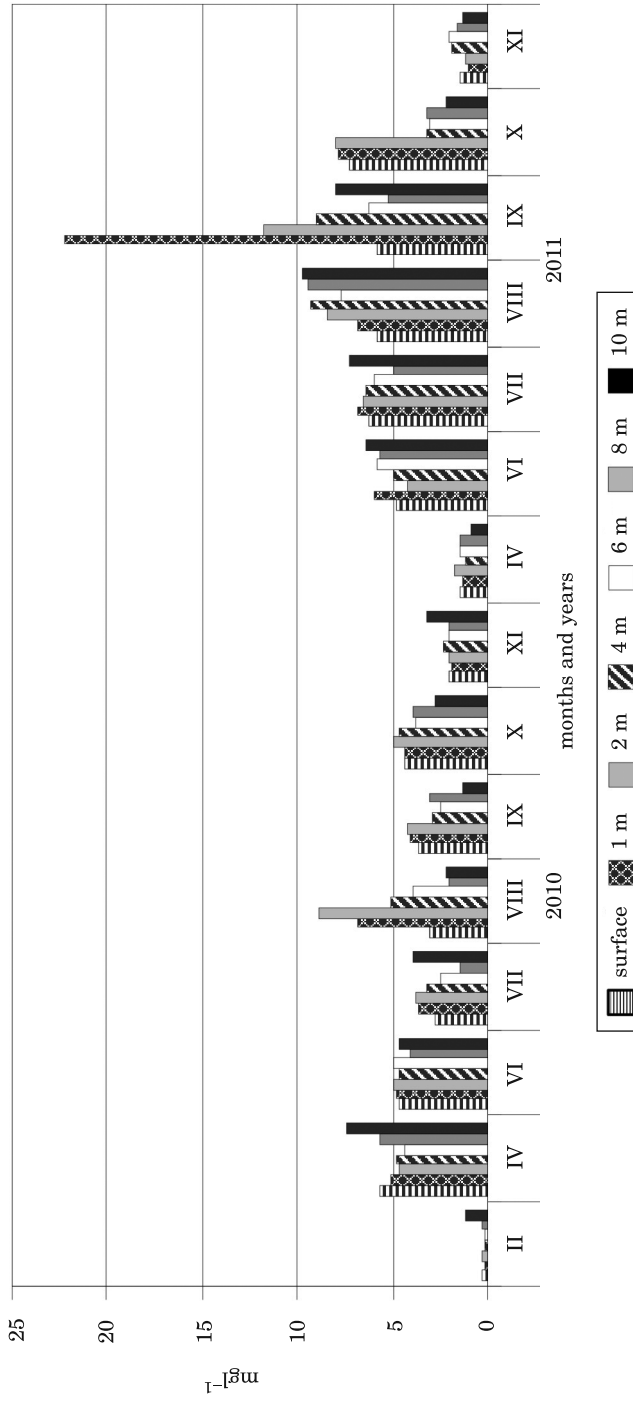

Fig. 4. Dry mass of seston concentration in Lake Sławskie

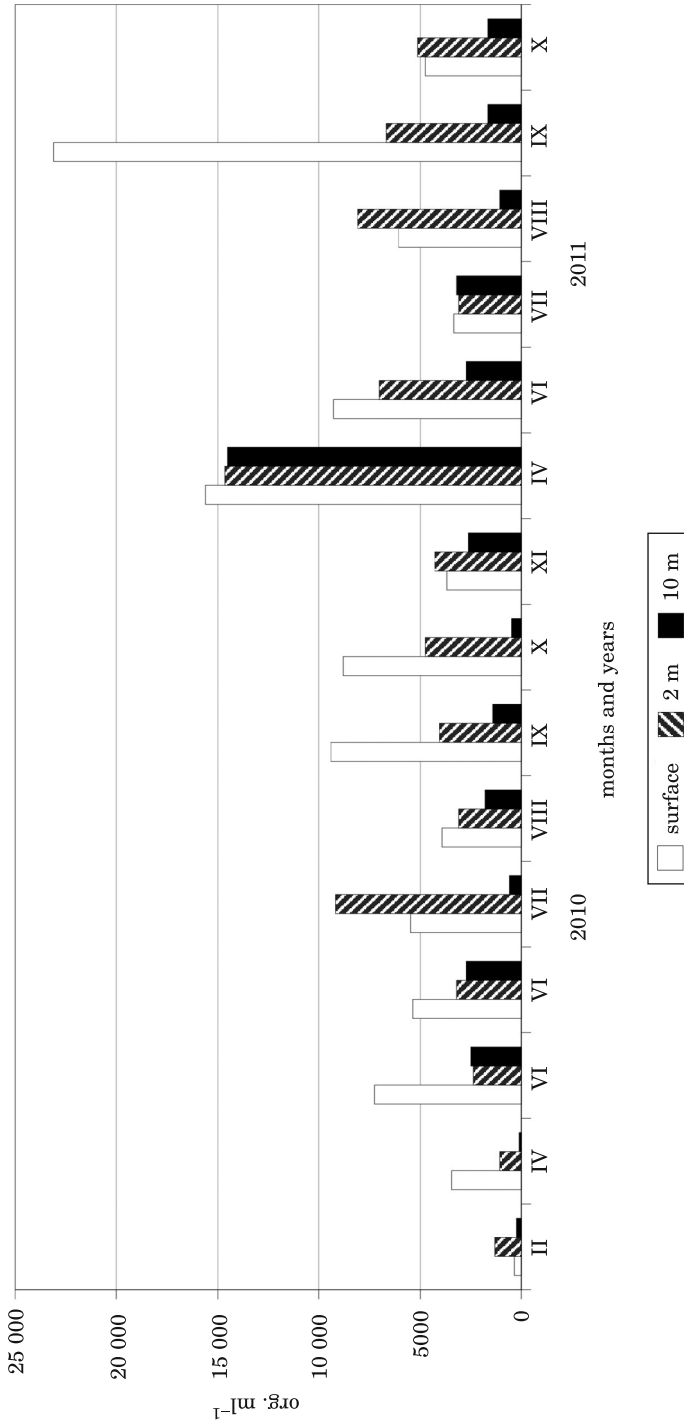

Fig. 5. Abundance of organisms belonging to individual taxonomic groups present in Lake Sławskie (examples from the surface and depth of 2 and 10 m)

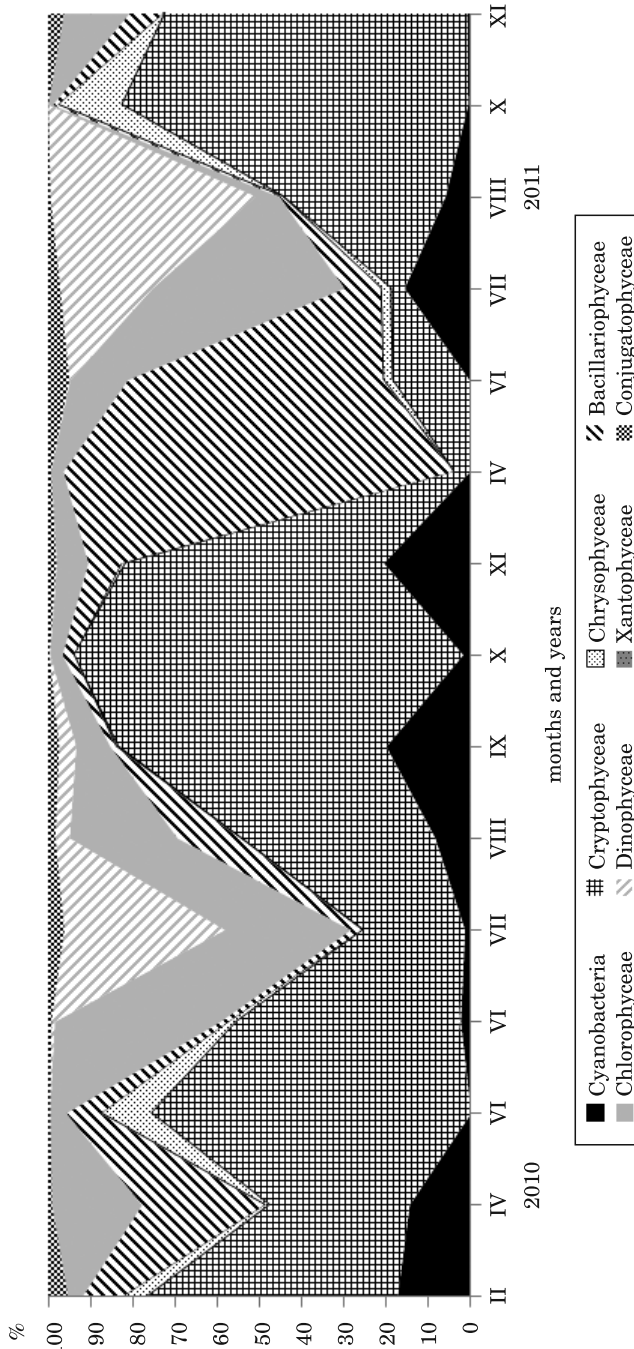

Fig. 6. Share of taxonomic groups in the total abundance of phytoplankton (example from a depth of 1 m)

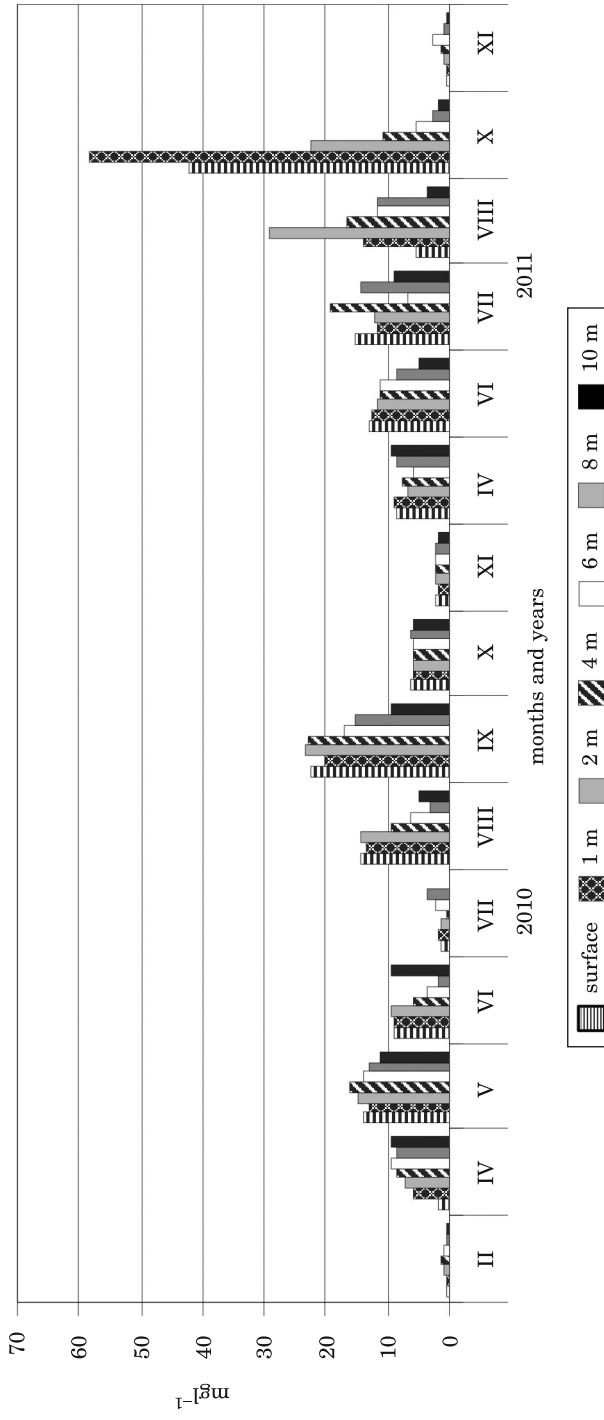

Fig. 7. Concentration of chlorophyll-a in the vertical profile of Lake Slawskie

The dry mass of seston concentration ranged from 0.1 to 22.2 mg l^{-1}. The largest value was noted in August 2011 (Figure 4). Taking into account such indicators as chlorophyll-a, conductivity, transparency, oxygen concentration in the hypolimnion, total nitrogen and phosphorus, the ecological status of Lake Sławskie was determined to be moderate.

The phytoplankton abundance in the investigated period varied from 100 org. ml^{-1} in March 2010 up to $23.1 \cdot 10^3$ org. ml^{-1} in October 2012 (Figure 5). The highest density of phytoplankton was especially caused by cryptophytes ($18 \cdot 10^3$ org. ml^{-1}). Also important were chrysophytes although less numerous in this period (Figure 6). These groups were usually present in the cold water periods (JACQUET et al. 2005, KOZAK 2009). The most numerous were *Rhodomonas lacustris* Pascher et Ruttner and *Cryptomonas marssonii* Skuja. These species were also the most numerous in many Polish lakes eg. Lake Strzeszyńskie in Poznań (SZELĄG-WASIELEWSKA 2006). In the same time in Lake Sławskie maximum chlorophyll-*a* concentration was noted reaching 58.4 μg l^{-1}. In remaining months it did not exceed 25 μg l^{-1} (Figure 7).

In Lake Sławskie the phenomenon of the self-restoration was observed. After the diversion of sewage inflow the improvement of water transparency was found. Some decrease in the abundance of cyanobacteria was noted in the phytoplankton. They reached only $1.7 \cdot 10^3$ org. ml^{-1} in September 2010. The most numerous species among cyanobacteria were *Aphanizomenon flos-aquae* (L.) Ralfs, *Cuspidothrix issatschenkoi* (Usachev) Rajaniemi and *Pseudanabaena limnetica* (Lemmermann) Komarek. These species are quite common indicators of high trophic level (SZELĄG-WASIELEWSKA 2006, BURCHARDT et al. 2007). They were noted in many eutrophic dam reservoirs and lakes (KOZAK 2005, BURCHARDT et al. 2007). There are among the number of species (about forty) of cyanobacteria belonging to different genera, which are potential toxin producers (PAWLIK-SKOWROŃSKA et al. 2004).

In the summer 2010 and 2011 the most abundant in Lake Sławskie were green algae and dinophytes, especially *Ceratium hirundinella* (O.F. Müller) Bergh. This species was the most numerous in August 2011. It is regarded as an indicator of meso-eutrophic waters (ROSEN 1981). It was also abundant in summer in many other lakes such as Lake Ostrowiec (GOŁDYN and SZELĄG-WASIELEWSKA 2004), Lake Łuknajno (JAWORSKA and KRUK 2007) and in restored Lake Głęboczek (JAWORSKA et al. 2009).

The group characterized by the greatest species richness was Chlorophyta. Its representatives were noted in all over the season. The highest density in this group was noted in July 2010 ($6.1 \cdot 10^3$ org. ml^{-1}). This is the most numerous group in many lakes and reservoirs (KOZAK 2005, 2009).

In spring centric diatoms (*Cyclotella* sp., *Stephanodiscus* sp.) grew in the reservoir. Their density reached $14.9 \cdot 10^3$ org. ml^{-1}. These genera favor

a turbulent environment such as water mixing and low light conditions. The domination of small centric diatoms is usually observed in the phytoplankton of eutrophic floodplain lakes (WOJCIECHOWSKA et al. 2007).

The bottom of the lake was covered by numerous molluscs (e.g. *Dreissena polymorpha*). Their influence on the water transparency was favourable due to the phytoplankton filtration.

Macrophytes as an effective factor improving water quality, were also monitored. The species of submerged plants such as *Batrachium circinatum, Najas marina*, *Ceratophyllum demersum* and *Myriophyllum spicatum* were present and increased the surface of their patches in the succeeding years. Macrophytes play a great role in the lake ecosystem e.g. create specific habitats (refuge) that support zooplankton proliferation (CELEWICZ-GOŁDYN et al. 2010, PATURA et al. 2012). What is more, the species richness of zooplankton increases along with an increase in habitat heterogeneity (KUCZYŃSKA-KIPPEN 2006). The macrofilter feeders are responsible for controlling the development of phytoplankton and improvements of water transparency (KOZAK and GOŁDYN 2004). The domination of macrophytes favor regression of phytoplankton including harmful cyanobacteria.

Conclusions

Lake Sławskie water studied in the period of 2010–2011 have had good quality. On the basis of physico-chemical variables of the water this lake was categorized as mezo-eutrophic. Taking into account such indicators as chlorophyll-a, conductivity, transparency, oxygen concentration in the hypolimnion, total nitrogen and phosphorus, the ecological status of the Sławskie Lake was determined to be moderate.

The lake was characterized by thermal and oxygen stratification within a period of summer. An ammonium nitrogen dominated among mineral forms of nitrogen. It reached 3.45 mg $N\text{-}NH_4$ l^{-1} in summer 2010 in the bottom layer. Both dissolved phosphates and total phosphorus concentrations reached 0.53 mg P l^{-1} and 0.61 mg P l^{-1} near the bottom layer in the summer 2010. In summer-time the least visibility was noted (1.2 m noted in June 2011). The highest density of phytoplankton was especially caused by cryptophytes, chrysophytes and diatoms. Cyanobacteria did not exceed 20% among phytoplankton groups. The presence of macrophytes and the increasing range of submerged plant communities in the succeeding years favour the restriction of the abundance of phytoplankton and the improvement of light transparency.

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EMPIRICAL AND PREDICTIVE EFFECTIVENESS OF STAGES IN CONTROLLED REPRODUCTION OF AFRICAN CATFISH *CLARIAS GARIEPINUS* BURCHELL 1822 – THE EFFECT OF FEMALE BODY WEIGHT

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Key words: controlled reproduction, ovulation stimulation, Ovopel, female body weight, *Clarias gariepinus*.

Abstract

The results of stages in controlled reproduction of African catfish *C. gariepinus* were investigated in females in six classes of body weight (I: >0 ≤1.5 kg; II: >1.5 kg ≤2.5 kg; III: >2.5 kg ≤3.5 kg; IV: >3.5 kg ≤4.5 kg; V: >4.5 kg ≤6.5 kg; VI: >6.5 kg), their ovulation being stimulated with Ovopel (1 pellet kg^{-1}). The accepted classification significantly ($P \leq 0.01$) differentiated the weight of obtained eggs expressed both in grams and in percentage of female body weight. The highest weight of eggs was obtained from the heaviest fish (class VI) and the lowest from these of the lowest weight (class I) (1191.8 g and 218.7 g respectively) while in these two classes the obtained highest weight of eggs was expressed as the percentage of female body weight (14.21% and 20.19% respectively). The class of body weight significantly ($P \leq 0.01$) determined also the two investigated traits which described the quality of eggs. The lowest value of the least squares means for the percentage of fertilization and of live embryos was noted for the heaviest fish (class VI) (64.75% and 54.63% respectively) and the highest for the fish of the lowest weight, i.e., classes I and II (91.67% and 88.17%, 92.47% and 86.33%). In general the highest effectiveness of reproduction characterized the class of females whose body weight exceeded 4.5 kg but did not rise above 6.5 kg. In order to predict the weight of eggs [g], percentage of fertilization [12 h] and percentage of live embryos [24 h] within the investigated classes the regression equation was introduced using the weight of females as an independent variable. For each class regression equations were also derived in which the weight of females and weight of eggs were accepted as independent variables while the percentages of fertilization and of live embryos were used as dependent variables. The value of empirical data concerning the weight of eggs [g], fertilization percentage [12 h] and percentage of live embryos [24 h] were the basis for deriving a square function which permitted spatial prediction of the distribution of points of these variables on a plane – for each class of female body weight separately.

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EMPIRYCZNE I PREDYKCYJNE EFEKTY ETAPÓW KONTROLOWANEGO ROZRODU SUMA AFRYKAŃSKIEGO *CLARIAS GARIEPINUS* BURCHELL 1822 – WPŁYW MASY CIAŁA SAMIC

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Słowa kluczowe: kontrolowany rozród, stymulowanie owulacji, Ovopel, masa ciała samic, *Clarias gariepinus*.

Abstrakt

Badano wyniki etapów kontrolowanego rozrodu samic suma afrykańskiego *Clarias gariepinus* należących do sześciu klas masy ciała (I: >0 ≤1,5 kg; II: >1,5 kg ≤2,5 kg; III: >2,5 kg ≤3,5 kg; IV: >3,5 kg ≤4,5 kg; V: >4,5 kg ≤6,5 kg; VI: >6,5 kg), u których stymulowano owulację Ovopelem (1 pellet kg^{-1}). Przyjęta klasyfikacja różnicowała istotnie ($P \leq 0{,}01$) masę ikry wyrażoną tak w gramach, jak i w procencie masy ciała ryb. Najwyższą masę jaj pozyskano od ryb najcięższych – klasa VI, a najniższą od najlżejszych – klasa I (odpowiednio 1191,8 g i 218,7 g), przy czym w tych dwóch klasach uzyskano najwyższą masę jaj wyrażoną jako procent masy ciała samic (odpowiednio 14,21% i 20,19%). Klasa masy ciała determinowała istotnie ($P \leq 0{,}01$) również dwie badane cechy określające jakość pozyskanej ikry. Najniższą wartość średniej najmniejszych kwadratów dla procentu zapłodnienia i żywych zarodków odnotowano dla ryb najcięższych (klasa VI) – odpowiednio 64,75% i 54,63%, a najwyższą dla ryb najlżejszych (klasa I i II) – odpowiednio 91,67% i 88,17% oraz 92,47% i 86,33%. Najwyższą efektywnością rozrodu charakteryzowała się klasa samic, których masa ciała przekraczała 4,5 kg, ale nie była wyższa niż 6,5 kg. W celu predykcji masy ikry [g], procentu zapłodnienia (12 godz.) oraz procentu żywych zarodków [24 godz.] w obrębie badanych klas wyprowadzono równania regresji, wykorzystując masę samic jako zmienną niezależną. Dla każdej klasy wyprowadzono również równania regresji, w których jako zmienne niezależne przyjęto masę samicy i masę ikry, a jako zmienne zależne – procent zapłodnienia i żywych zarodków. Wartości danych empirycznych odnośnie do masy jaj [g], procentu zapłodnienia (12 godz.) oraz procentu żywych zarodków [24 godz.] stanowiły podstawę do wyprowadzenia funkcji kwadratowej pozwalającej na przestrzenną predykcję rozkładu punktów tych zmiennych na płaszczyźnie – oddzielnie dla każdej klasy masy ciała samic.

Introduction

In numerous fish species the dependence of the effects of controlled reproduction on the body weight of spawning females seems to present a serious problem in hatchery practice and in general in the fishery. The results of numerous studies show that heavier females (most often older), usually yield eggs of a higher mass compared with that obtained from females of a lower one (KAMLER and MALCZEWSKI 1982, BRZUSKA 1991, 2001a,b, 2010, CEJKO 2007). The diameter and weight of eggs obtained from females of a high body weight also most frequently exceed the diameter and weight of eggs

yielded by light females (ZONOVA 1973, HULATA and MOAV 1974, KAMLER and MALCZEWSKI 1982, KAMLER and KATO 1983, KORWIN-KOSSAKOWSKI 1989, BRZUSKA 1997, ADAMEK et al. 2011). The known fact is that older spawners not always exceed the body weight of younger fish. In hatchery practice the age of spawners is not always known hence in selecting fish for controlled reproduction the easiest criterion is their body weight. However, it is worth noting that the maintenance of heavy spawners is very expensive on account of higher costs of feeding, service, and the heating and utilization of water. Besides, it necessitates a wider space in tanks where the heavy spawners are kept. The heavy females are treated with large amounts of expensive ovulation stimulators whose doses are calculated per 1 kg body weight of spawners. Compared with lighter females, those of the higher body weight are to a greater degree exposed to mechanical damage during all the treatments and manipulations connected with the preparation and performance of reproduction under controlled conditions.

In the case of *Clarias gariepinus*, like of other stenothermal fish species, the opinions concerning the use of females of a higher body weight for controlled reproduction are not unequivocal. ADAMEK (2001) suggests that the best effects of reproduction are obtained from females two – three years of age and the body weight of about 4 kg.

In the research carried out in our Institute attempts were made to show if in the effects of reproduction of this fish species differences could be found depending on the body weight of females whose ovulation was stimulated, among other preparations, with CPH (BRZUSKA 2001a, 2002), Ovopel (BRZUSKA 2001a, 2002), Aquaspawn (BRZUSKA 2003a), or Lecirelin (BRZUSKA et al. 2004). It should be noted that the experiments were carried out in the course of spawning of a small number of females divided only in two groups of body weight.

The aim of the investigation described in the presented paper was to compare the effects of reproduction of *Clarias gariepinus* females in six classes of body weight, stimulated with the most frequently used ovulation stimulator i.e., Ovopel. Model considerations were also carried out concerning the prediction of the effectiveness of reproduction within the investigated body weight classes of females.

Materials and Methods

The data used as the material for calculations were derived from nine controlled spawning carried out in the Institute of Ichthyobiology and Aquaculture of the Polish Academy of Sciences at Gołysz. 71 females

(0.91–9.40 kg) reared in the Institute were used for propagation. For each spawning females were selected from a greater population of spawners on the basis of the external signs of maturity (soft and large abdomen). Groups of two fish each were placed in tanks 2.5 m^3 in water at 24–25°C. The ovulation stimulation was carried out with one peritoneal dose (1 pellet kg^{-1}) of Ovopel (BRZUSKA et al. 1998, 2000), prepared according to the procedure given by HORVÁTH et al., 1997. The concentrations of D-Ala^6,Pro^{9}NEt-mGnRH-a and metoclopramide were 18–20 μg/pellet and 8–10 mg/pellet.

The fish were checked for ovulation by a gentle pressing of the abdomen (DE LEEUW et al. 1985, GOOS et al. 1987). Eggs obtained from each female separately were weighed and fertilized with pooled milt from macerated testes of three – four killed males (INYANG and HETTIARACHCHI 1994), which were not treated with Ovopel before. The incubation of fertilized eggs from each females separately was conducted in a Weiss glass (7L) at 24–25°C. After 12 h incubation, the percentage of fertilized eggs and after 24 h incubation the percentage of living embryos were calculated for individual females. Statistical characteristics of the data are given in Table 1.

Since the spawning was carried out in different years the multiplier corrections were estimated for a year and using them every observation was corrected (MILLER et al. 1966).

The following classification of females was carried out, their body weight being taken into consideration. Class I: >0 ≤1.5 kg; class II: >1.5 kg ≤2.5 kg; class III: >2.5 kg ≤3.5 kg; class IV: >3.5 kg ≤4.5 kg; class V: >4.5 ≤6.5 kg; class VI: >6.5 kg.

For the classified data analysis of variance was carried out using the least-squares method (HARVEY 1987) in order to estimate the effect of the class of female body weight on the investigated traits. The investigated traits describing the effects of stages in reproduction were the weight of eggs in grams, weight of eggs as percentage of female body weight, the percentage of fertilization after 12 h incubation, and the percentage of living embryos after 24 h incubation.

Analysis of variance was carried out according to the following linear model:

$$Y_{ij} = \mu + k_i + e_{ij}$$

where:
μ – the overall mean,
k_i – the effect of class of female body weight (i =1...6),
e_{ij} – the random error associated with observation j.

The analysis allowed to estimate the constants and means of the least squares which showed the values of the investigated traits within six classes of female body weight. The values of constants and least squares means are given in Table 2.

Table 1

Statistical characteristics of female body weight, weight of obtained eggs expressed in grams and in percentage of female body weight, fertilization percentage (12 h) and percentage of living embryos (24 h) in six classes of female body weight (I–VI)

Investigated traits	Descriptive statistics			
	n	$\bar{x}$	SD	S_e
Weight of females [kg]				
I	9	1.19	0.19	0.06
II	16	2.03	0.32	0.08
III	17	3.06	0.31	0.07
IV	12	3.95	0.27	0.07
V	7	5.43	0.43	0.16
VI	10	8.15	0.85	0.28
Weight of eggs [g]				
I	7	227.57	50.69	19.16
II	16	232.81	103.38	25.85
III	17	368.29	117.57	28.51
IV	12	489.92	181.50	52.40
V	7	495.33	239.92	97.95
VI	9	1163.78	516.09	172.03
Weight of eggs [% of female body weight]				
I	7	20.04	5.07	1.92
II	16	11.39	4.37	1.09
III	17	11.90	3.20	0.78
IV	12	12.33	4.14	1.19
V	7	9.15	4.27	1.74
VI	9	13.95	5.12	1.71
Fertilized eggs after 12 h incubation [%]				
I	6	91.67	4.50	1.84
II	15	92.47	4.36	1.12
III	16	77.41	20.25	4.91
IV	11	76.18	20.86	6.29
V	7	90.17	5.60	2.29
VI	8	66.88	11.00	3.89
Live embryos after 24 h incubation [%]				
I	6	88.17	6.88	2.80
II	15	86.33	8.76	2.26
III	16	71.59	22.13	5.37
IV	11	68.45	19.47	5.87
V	7	82.50	10.43	4.26
VI	8	56.50	7.69	2.72

$\bar{x}$ – arithmetical mean; SD – standard deviation; S_e – standard error of the mean

Table 2

Constants (LSC) and least squares means (LSM) for investigated reproduction traits within six classes of female body weight and results of F-test

Classes of female body weight	Weight of eggs [g] μ= 497.33				Weight of eggs [% of female body weight] μ= 13.19				Percentage of fertilized eggs after 12 h incubation μ= 83.62				Percentage of living embryos after 24 h incubation μ= 76.80			
	LSC	LSM	$S\bar{e}$	F**	LSC	LSM	$S\bar{e}$	F**	LSC	LSM	$S\bar{e}$	F**	LSC	LSM	$S\bar{e}$	F**
I	–278.66	218.67	97.37	–	6.99	20.19	1.73	–	8.05	91.67	4.02	–	11.36	88.17	4.43	–
II	–258.33	239.00	61.58	–	–1.39	11.80	1.09	–	8.85	92.47	2.55	–	9.53	86.33	2.80	–
III	–141.01	356.31	59.63	–	–1.72	11.48	1.06	–	–2.75	80.88	2.47	–	–1.11	75.69	2.71	–
IV	–14.43	482.90	75.42	–	–0.87	12.32	1.34	–	–1.82	81.80	3.12	–	–3.30	73.50	3.43	–
V	–1.99	495.33	97.37	–	–4.04	9.15	1.73	–	6.55	90.17	4.03	–	5.70	82.50	4.43	–
VI	694.42	1191.75	84.33	–	1.02	14.21	1.50	–	–18.87	64.75	3.49	–	–22.17	54.63	3.83	–

μ – overall means; $S\bar{e}$ – standard error of least squares means (**$P \leq 0.01$).

The significance of the main classification factor on the investigated traits was tested using the F-test (Table 2) and the Duncan's multiple range test was used for the analysing the significance of differences between the means of the six classes of female body weight (Table 3). For each body weight class the percentage of females in which the ovulation occurred (Figure 1) and also the phenotypic correlations between the investigated traits were calculated (Table 4).

Table 3

Significance of differences between the means of class female body weight for the weight of eggs (expressed in grams and in percentage of fish body weight), percentage of egg fertilization (12 h) and for percentage of living embryos (24 h) (Results of Duncan's test; *$P \leq 0.05$; **$P \leq 0.01$)

Class of female body weight	Weight of eggs in grams						Class of female body weight	Weight of eggs [in % of female body weight]					
	I	II	III	IV	V	VI		V	III	II	IV	VI	I
I	1	–	*	*	*	**	V	1	–	–	–	*	**
II		1	*	**	*	**	III		1	–	–	–	**
III			1	*	*	**	II			1	–	*	**
IV				1	–	**	IV				1	–	**
V					1	**	VI					1	**
Class of female body weight	**percentage of fertilized eggs after 12 h incubation of eggs**						**class of female body weight**	**percentage of living embryos after 24 h incubation of eggs**					
	VI	IV	III	V	II	I		VI	IV	III	V	II	I
VI	1	**	**	**	**	**	VI	1	**	**	**	**	**
IV		1	–	**	**	**	IV		1	–	**	**	**
III			1	**	**	**	III			1	*	**	**
V				1	–	–	V				1	*	*
II					1	–	II					1	–

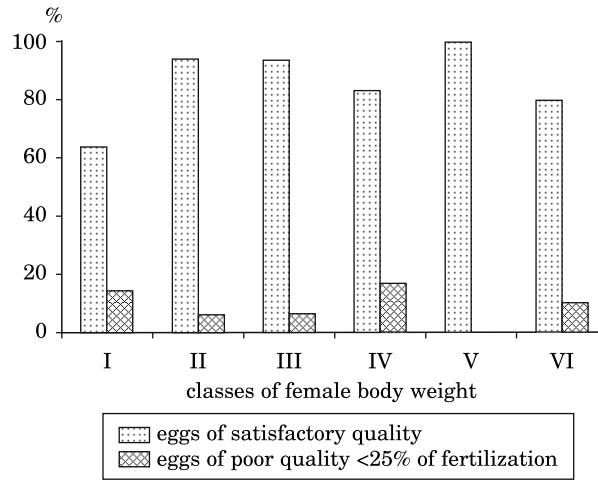


Fig. 1. Percentage of ovulating females after hormonal stimulation

Table 4

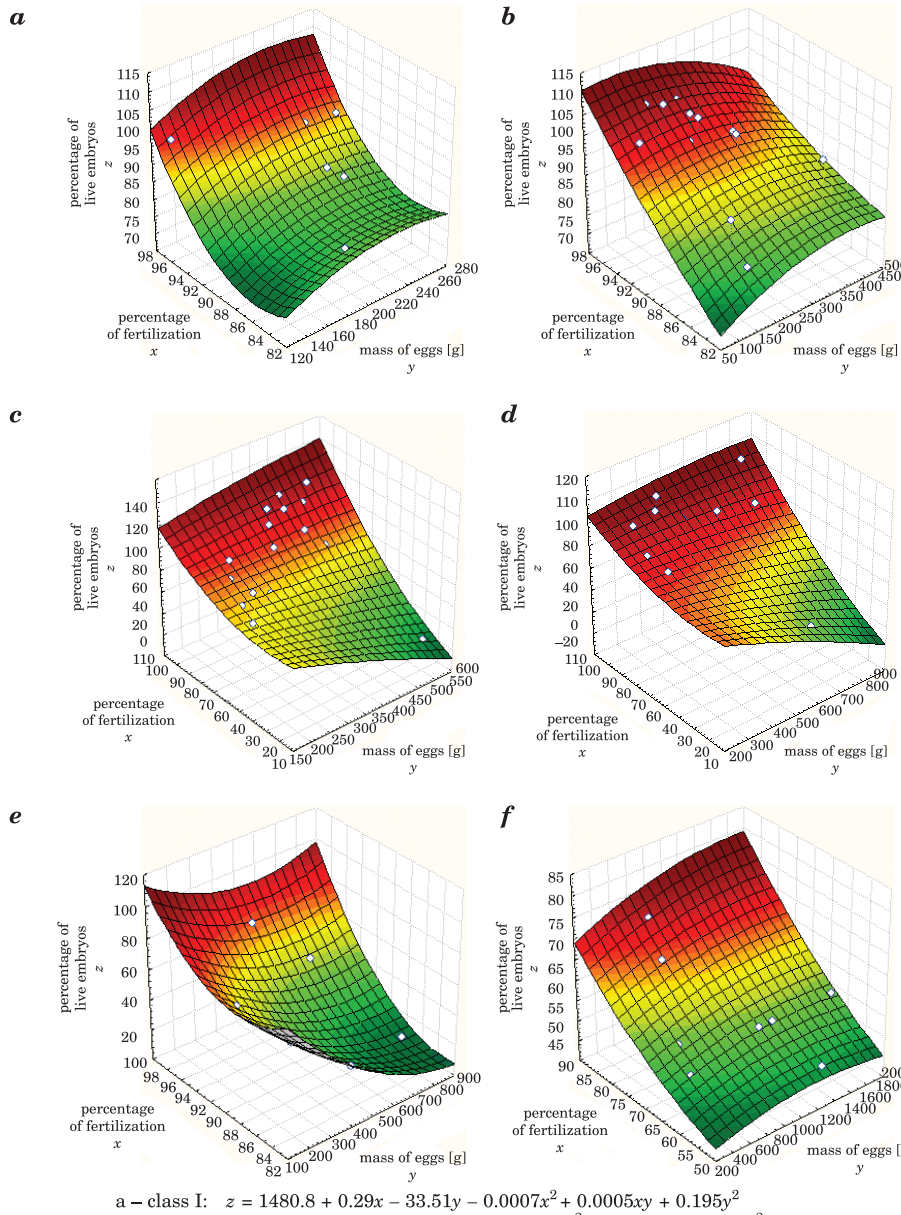
Correlation between the body weight of females, weight of eggs (expressed in grams and in percentage of female body weight), percentage of fertilized eggs (12 h) and percentage of living embryos (24 h) within six classes of female body weight (I–VI)

Investigation traits	Classes of female body weight	Body weight of females [kg] 1)	Weight of eggs [g] 2)	Weight of eggs [% of female body weight] 3)	Percentage of fertilized eggs after 12 h incubation 4)	Percentage of living embryos after 24 h incubation 5)
1	I	x	0.49	–0.81*	0.82*	0.80
	II	x	0.57*	0.21	–0.07	–0.13
	III	x	0.72*	0.50*	0.49*	0.49*
	IV	x	0.51	0.37	–0.44	–0.49
	V	x	0.17	–0.04	–0.48	–0.58
	VI	x	0.84*	0.73*	–0.83	–0.72*
2	I		x	0.90*	–0.14	–0.25
	II		x	0.91*	–0.09	–0.12
	III		x	0.96*	0.20	0.09
	IV		x	0.99*	–0.03	–0.08
	V		x	0.98*	0.13	–0.55
	VI		x	0.98*	–0.58	–0.48
3	I			x	–0.47	–0.54
	II			x	–0.06	–0.05
	III			x	0.06	–0.08
	IV			x	0.05	0.02
	V			x	0.24	–0.42
	VI			x	–0.46	–0.37
4	I				x	0.96*
	II				x	0.87*
	III				x	0.97*
	IV				x	0.96*
	V				x	0.73
	VI				x	0.96*

* Correlation significant at $P \leq 0.05$

The female body weight being used as an independent variable, regression equations were worked out within the investigated classes, the weight of eggs, fertilization percentage (12 h) and percentage of living embryos (24 h) being used as dependent variables. For each class of female body weight regression equations were derived, the female body weight but also the weight of obtained eggs being accepted as independent variables and the percentage of fertilization (12 h) and percentage of live embryos (24 h) as a dependent variable. The percentage of the explained variability was characterized by the determination index (R^2) as the adequacy of the equation matching the real system.

The values of empirical data concerning such variables as the weight of eggs expressed in grams, percentage of fertilization, and percentage of living embryos (24 h) were the basis of deriving a square function which allowed



a – class I: $z = 1480.8 + 0.29x - 33.51y - 0.0007x^2 + 0.0005xy + 0.195y^2$
b – class II: $z = 60.55 + 0.29x - 1.80y - 8.6818E-5x^2 - 0.0027xy + 0.022y^2$
c – class III: $z = 77.55 - 0.12x - 0.64y - 4.4664E-5x^2 + 0.0019xy + 0.0066y^2$
d – class IV: $z = 72.18 - 0.079x - 0.51y - 2.9134E-5x^2 + 0{,}0013xy + 0.0057y^2$
e – class V: $z = 1366.07 - 0.27x - 28.36y + 5.0823E-5x^2 + 0.0021xy + 0.16y^2$
f – class VI: $z = 47.46 + 0.003x - 0.53y - 2{,}8148E-6x^2 + 0.0001xy + 0.0083y^2$

Fig. 2. Surface charts for weight of eggs in grams (y), percentage of fertilization (x) and percentage of live embryos after 24 hours incubation (z) fitted by the square function

to predict the distribution of points of these variables on a plane – for each class of female body weight separately (Figure 2).

Results

Percentage of females ovulating after hormonal stimulation

In class I ovulation occurred in 77.80% of females, however, in 14.3% of fish treated with Ovopel the obtained eggs were of a very poor quality (Figure 1). In classes II and III respectively 94.12% and 93.75% of fish yielded eggs of satisfactory quality, while only 5.88% and 6.25% of poor quality (Figure 1).

The highest percentage of fish giving eggs of a low fertilization percentage was noted in class IV (16.67%; Figure 1) while in this class eggs of satisfactory quality were yielded by 83.33% of females (Figure 1). In class V eggs of good quality were obtained from all the fish after the Ovopel treatment (Figure 1). In the class of fish of the highest body weight (VI) ovulation occurred in 90% of females and eggs of satisfactory quality were obtained from 80% of fish treated ith the ovulation stimulator (Figure 1).

Effect of the female body weight class on the weight and quality of the eggs

A statistically significant effect of the main classification factor was found for the weight of eggs expressed both in grams and in percentage of female body weight ($P \leq 0.01$, $P \leq 0.01$; Table 2). The highest weight of eggs expressed in grams was obtained in class VI and the lowest one in class I (1191.75 g and 218.67 g); the difference between the means for these groups being 973.08 (Table 2). The least squares mean for class VI deviated from the overall mean for this trait by as many as +694.42 g (Table 2). It is worth noting that the means for successive classes of female body weight were characterized by an ascending tendency (Table 2).

The least squares means for the weight of eggs expressed in the percentage of female body weight show that the highest value of this trait was found in classes I and VI, and the lowest one in class V (20.19%, 14.21% and 9.15% respectively). In groups II, III, and IV the means had a similar value (within the range of 11.48% and 12.32%), all three means deviated in minus from the overall mean (Table 2).

The class of female body weight also significantly differentiated the investigated traits which characterized the quality of eggs ($P \leq 0.01$, $P \leq 0.01$; Table 2).

The lowest value of the least squares mean for the fertilization percentage was noted in class VI and the highest in classes I and II (64.75%, 91.67% and 92.47% respectively; Table 2). It should be stressed that the mean for class VI deviated from the overall mean by as many as –18.87%. The means for classes III and IV also deviated in minus from the overall mean for this trait, however, by ~2% only (Table 2). The least squares means which characterized the percentage of live embryos after 24 h incubation showed the highest values for classes I and II, attaining 88.17% in class I and 86.33% in class II (Table 2). The lowest least square mean of 54.63% for this trait was noted in class VI. This value deviated from the overall mean for this trait by as many as -22.13% (Table 2).

The results of the Duncan's multiple range test given in Table 3 show the significance of differences between the means of the investigated traits calculated for the different classes of the female body weight. The results of this test showed that differences between means characterizing weight of eggs in grams of all the investigated classes are significant except for the difference between classes I and II and classes IV and V (Table 3). Differences between the means characterizing the weight of eggs expressed in percentage of female body weight were statistically significant for class I and all the remaining classes of female body weight and for classes V and VI as well as classes II and VI (Table 3). The mean fertilization percentage significantly differed between class VI and all the remaining investigated classes, between class IV and V, II, I, as well as between class III and V, II, I. (Table 3). Differences between all means determining the percentage of live embryos were statistically significant except for the difference between classes IV and III as well as classes II and I (Table 3).

Dependences between the investigated traits

The body weight of females which responded with ovulation to the hormonal stimulation was positively correlated with the weight of obtained eggs (expressed in grams) in all the classes of female body weight. The highest statistically significant ($P \leq 0.05$) value of the index of correlation between these traits was found for classes VI, III and II (+0.84; +0.72; and +0.57 respectively) and the lowest for class V (+0.17; Table 4). The statistically significant positive correlation between the female body weight and the percentage of egg fertilization was found for body weight classes I and III, the highest value of the correlation coefficient being noted in the case of class I (Table 4). The female body weight also was positively correlated with the percentage of live embryos after 24 h incubation only in classes I and III (+0.80 and +0.49

respectively; Table 4). The index of correlation between these traits had the lowest value (–0.13) in the group of fish in body weight class II (Table 4). Correlation between the weight of eggs expressed in grams and the weight of eggs expressed in percentage of female body weight was positive in all the investigated classes, the value of the correlation index varying in the range of +0.90 to +0.98 (Table 4). The weight of eggs expressed in grams was positively correlated with the fertilization percentage only in the group of fish in body weight classes III and V, however, the value of the correlation coefficient for these classes was low (+0.20 and +0.13 respectively; Table 4). Correlation between the weight of eggs expressed in grams and the percentage of live embryos after 24h incubation was negative in all the classes of body weight of females, except for class III (Table 4). A positive statistically significant correlation between the fertilization percentage and percentage of live embryos after 24 h incubation was noted for all investigated classes of females except for group V (Table 4).

Regression predictions

In the regression equations given in Table 5 the dependent variables were: the weight of eggs expressed in grams, the percentage of fertilization after 12 h and that of live embryos after 24 h incubation; the independent variable was the female body weight. Analysis of values of the determination index (R^2) given with the equations where a dependent variable was the weight of eggs, showed that the highest R^2 was found for class VI, a slightly lower for class III and the lowest for class I (0.64, 0.52 and 0.01 respectively; Table 5). If the dependent variable was the fertilization percentage and the percentage of live

Table 5

Regresion predictions and determination indices (R^2) estimated within six classes of female body weight for the weight of eggs [g], percentage of fertilized eggs after 12 h incubation and the percentage of living embryos after 24 h incubation

Classes of body weight	Equations of regression	R^2	Equations of regression	R^2	Equations of regression	R^2
I	$y_1 = 235.74 - 7.01x_1$	0.01	$y_2 = 67.82 + 21.38x_1$	0.66	$y_3 = 52.43 + 32.05x_1$	0.64
II	$y_1 = -89.05 + 161.33x_1$	0.28	$y_2 = 94.33 - 0.93x_1$	0.01	$y_3 = 93.42 - 3.53x_1$	0.02
III	$y_1 = -461.41 + 271.51x_1$	0.52	$y_2 = -19.94 + 31.86x_1$	0.24	$y_3 = 33.98 + 34.55x_1$	0.24
IV	$y_1 = -823.24 + 332.72x_1$	0.24	$y_2 = 204.62 - 32.62x_1$	0.19	$y_3 = 202.61 - 34.07x_1$	0.24
V	$y_1 = -8.5 + 89.84x_1$	0.03	$y_2 = 121.23 - 5.73x_1$	0.22	$y_3 = 152.87 - 12.98x_1$	0.34
VI	$y_1 = -2779.0 + 483.85x_1$	0.64	$y_2 = 148.93 - 10.03x_1$	0.63	$y_3 = 106.32 - 6.08x_1$	0.52

Dependent variables: y_1 – weight of eggs [g]; y_2, percentage of fertilized eggs after 12 h incubation; y_3 – percentage of living embryos after 24 h incubation, independent variable: x_1 – body weight of females [kg]

embryos, the R^2 obtained the highest value in class I (0.66 and 0.64 respectively), however, high values of this index were also found in class VI (0.63 and 0.52 respectively; Table 5). The lowest R^2 values were noted for class II of female body weight (0.01 and 0.02; Table 5).

The regression equations were given in Table 6, where the dependent variables were the percentages of fertilization and of live embryos, the independent variables being the weight of females as well as the weight of obtained eggs. The values of the determination index (given with the equations whose dependent variable was the percentage of egg fertilization) were found for class I and class VI (0.75 and 0.73 respectively) while the lowest value was noted for class II (0.01; Table 6). The values of this index for classes III, IV and V were similar (0.30; 0.24; 0.27; Table 6). In the case of the percentage of live embryos after 24 h incubation being the dependent variable, the highest value of the determination index was also found in classes I, VI and V (0.67, 0.56 and 0.55) and the lowest one in class II (0.02) – Table 6.

Table 6

Regression predictions and determination indices (R^2) estimated within six classes of female body weight for the percentage of fertilized eggs after 12 h incubation and percentage of living embryos after 24 h incubation

Classes of body weight	Equations of regression	R^2	Equations of regression	R^2
I	$y_2 = 55.94 + 25.83x_1 + 0.032x_2$	0.75	$y_3 = 42.50 + 35.76x_1 + 0.026x_2$	0.67
II	$y_2 = 93.88 - 0.29x_1 - 0.004x_2$	0.01	$y_3 = 92.71 - 2.52x_1 - 0.006x_2$	0.02
III	$y_2 = -46.92 + 47.73x_1 - 0.06x_2$	0.30	$y_3 = -82.79 + 63.26x_1 - 0.11x_2$	0.39
IV	$y_2 = 229.34 - 42.46x_1 + 0.03x_2$	0.24	$y_3 = 223.53 - 42.41x_1 + 0.02x_2$	0.28
V	$y_2 = 121.19 - 6.19x_1 + 0.005x_2$	0.27	$y_3 = 153.04 - 11.18x_1 - 0.02x_2$	0.55
VI	$y_2 = 170.96 - 14.03x_1 + 0.009x_2$	0.73	$y_3 = 122.01 - 8.94x_1 + 0.006x_2$	0.56

Dependent variables: y_2 – percentage of fertilized eggs after 12 h incubation; y_3 – percentage of living embryos after 24 h incubation, independent variables: x_1 – weight of female [kg]; x_2 – weight of eggs [g]

Distribution of values of the analysed traits in a special system

By analysing the shape of spacially arranged planes, the value of absolute term and values of variables X and Y, we could see that they were distinctly different for the investigated class of female body weight for the analysed arrangement (Table 7, Figure 2). The value of the multiple correlation coefficient allows to state that the best fit of the distribution of points to the plane is obtained for class II and the worse one to class VI.

Table 7

Main components of the square equation used for derivation of surface charts (*R* – mutiple correlation coefficient)

Arrangement of variables	Class of female body weight	Absolute term	*X*	*Y*	*R*
A	I	1480.80	0.29	–33.51	0.86
	II	60.55	0.29	–1.80	0.97
	III	70.55	–0.12	–0.64	0.89
	IV	72.18	–0.079	–0.51	0.88
	V	1366.07	–0.27	–28.36	0.85
	VI	47.46	0.003	–0.53	0.69

A – a set of variables: mass of eggs [g], percentage of fertilization [12 h], percentage of live embryos after 24 h incubation

Discussion

The obtained results showed that in the class of fish of the body weight exceeded 4.5 kg but did not rise above 6.5 kg ovulation occurred in 100% of females treated with Ovopel. It is worth stressing that of all the investigated classes in the above class only the obtained eggs were characterized by the satisfactory quality. In classes II (body weight of females >1.5 ≤2.5 kg) and III (body weight of females >2.5 ≤3.5 kg) ovulation also occurred in all the females, however, in both classes a low percentage of females yielded eggs of poor quality. In the class of fish of the least weight, i.e., whose body weight did not exceed 1.5 kg, ovulation was noted in the lowest percentage of females. In this class a high percentage (reaching 14.3%) of fish yielded eggs of poor quality. The highest percentage (16.67%) of fish yielding eggs with the fertilization percentage below 25% characterized the class of females of the body weight exceeding >3.5 ≤4.5 kg. It can be noted, in general, that in the classes of females of the least and the highest weight the percentage of fish ovulating after Ovopel treatment reached the lowest value.

In the Institute of Ichthyobiology and Aquaculture at Gołysz it was already attempted in previous studies to show dependences between the body weight of *Clarias gariepinus* females and reproduction effectiveness of this fish species after ovulation stimulation not only with Ovopel but also with carp pituitary homogenate (CPH). The results of the investigation showed that after the Ovopel stimulation females of the mean body weight of 3.80 kg as well as these of the mean body weight of 8.74 kg spawned in 100%. In the case of ovulation stimulation with carp pituitary homogenate eggs were obtained from only 67% of heavier fish while the ovulation occurred in all the fish of a lower body weight (BRZUSKA 2001a). The results of studies on the European catfish

Silurus glanis allowed to note that irrespective of the applied stimulator (CPH or Ovopel) females of the lower body weight (~5 kg) spawned in a higher percentage compared with heavier females (~12 kg) (BRZUSKA 2001b).

It was found on the basis of the presented investigation that the highest weight of eggs was given by the heaviest fish, i.e., the females of the body weight of 6.5 kg and above 6.5 kg, however, only in the case when the weight of eggs was expressed in grams. When the weight of eggs was expressed in the percentage of female body weight the highest value of the least squares mean for this trait was noted for the class of females of the least body weight, i.e., for fish whose body weight did not exceed 1.5 kg. A similar dependence was observed in the investigation of carp *Cyprinus carpio* carried out by CEJKO (2007). The results of the above investigation showed that in the class of the heaviest females the highest weight of eggs was obtained and in the class of the fish of the least body weight – the lowest, however, only in the case of expressing it in grams. The observation which was worth stressing showed that this dependence did not only occur after Ovopel stimulation of ovulation but also after the application of CPH (CEJKO 2007). Analysis of values of the least squares means which characterized the weight of eggs expressed in grams, calculated for the investigated classes of body weight of *Clarias gariepinus* females showed that these values had an ascending tendency in the successive classes of fish body weight. The same tendency was observed in the case of the carp irrespective of the preparation (Ovopel or CPH) used in ovulation stimulation (CEJKO 2007).

The results of studies of *Clarias gariepinus* carried out in the Institute of Ichthyobiology and Aquaculture at Gołysz in previous years showed that from females of the mean body weight of 8.9 ± 0.7 kg the weight of obtained eggs after Ovopel treatment was significantly higher compared with the weight of eggs obtained from females of the mean body weight of 3.8 ± 0.4 kg, but only in the case of the weight of eggs expressed in grams (BRZUSKA 2002). This observation confirmed the results obtained in the investigation of *Clarias gariepinus* in which the data were subjected to analysis of variance according to the linear model with the interaction between the ovulation stimulator and the body weight of females included (BRZUSKA 2001a).

Analysis of the results of controlled reproduction in this fish species in conditions of ovulation stimulation with CPH and also Aquaspawn preparation (containing GnRH-a and domperidon) shows that the fish of a mean body weight of 6.96 ± 0.72 kg released eggs of a higher weight (by 133 g) compared with the weight of eggs obtained from females of a lower mean body weight (4.89 ± 0.49 kg) (BRZUSKA 2003a). The results of an experiment with ovulation stimulators CPH and [D-Tle^{6},ProNHEt^{9}]mGnRH (Lecirelin; brand name Supergestran) also show that irrespective of the applied preparation from

females of the higher body weight (3.91 ± 0.23 kg) the weight of eggs expressed in grams was distinctly higher than that from fish of the lower weight (2.63 ± 0.36 kg). It is worth stressing that the interaction between the ovulation stimulator and the body weight of females was statistically significant both in the case of the weight of eggs expressed in grams and in percentage of the body weight of fish used in the reproduction (BRZUSKA et al. 2004).

In was found in an investigation carried out in our Institute with European catfish *Silurus glanis* females of the mean body weight of 5.67 kg and 10.00 kg that both after hypophysation and after one dose of Ovopel a higher weight of eggs expressed in grams was obtained from heavier fish. In the case of presenting the weight of eggs as percentage of body weight of females after ovulation stimulation with Ovopel the value of the least square means for this trait was higher for fish of a lower body weight (BRZUSKA 2000).

In the case of ovulation stimulation with CPH in females of European catfish *Silurus glanis* of the mean body weight of 5.0 ± 0.4 kg and 7.00 ± 0.6 kg BRZUSKA and ADAMEK (2002) did not find statistical differences in the weight of obtained eggs.

An attempt was undertaken by BRZUSKA (2001b) to find dependences between the body weight of European catfish *Silurus glanis* females and the weight of obtained eggs; the mean body weight of the investigated females was 5.20 kg or 11.80 kg. The results of this study show similar mean values of the weight of eggs expressed in grams obtained from fish after hypophysation of higher or lower body weight, while after the application of Ovopel fish of a higher body weight released eggs of a considerably higher weight.

The effect of the body weight of carp *Cyprinus carpio* females on traits determining the weight of obtained eggs was investigated by CEJKO (2007). This author showed that the class of weight of female body significantly determined the weight of eggs in grams. The lowest weight of eggs was found for females of the lowest body weight (above 3 kg but not exceeding 5 kg) and the highest for females of the body weight exceeding 11 kg, irrespective of the applied ovulation stimulator (CPH or Ovopel).

The results of studies reported in the presented paper which concern the quality of eggs from females divided into six classes of body weight, show that the highest percentage of fertilization characterized eggs from females of the body weight not exceeding 2.5 kg, i.e., females of classes I and II. It should be distinctly stressed that during the next 12 h of incubation the quality of eggs from females of these classes did not deteriorate and the percentage of live embryos was high, exceeding 86%, in the two classes. A sufficiently good quality of eggs given by females of a low body weight (below 2.5 kg) was also noted in earlier studies on the stimulation of African catfish with Dagin (BRZUSKA 2011) and also with human chorionic gonadotropin – Biogonadyl (BRZUSKA et al. 2000).

The lowest quality expressed as the percentage of fertilization and live embryos after 24 h incubation characterized eggs from females of the highest body weight, i. e, exceeding 6.5 kg. The mean fertilization percentage of eggs from females of this body weight class did not reach 65%, while the mean percentage of live embryos was as low as 54%. High mean fertilization percentages in females of class V, i.e., whose body weight exceeded 4.5 kg but did not rise above 6.5 kg, should be stressed as well as the high mean percentage (82%) of live embryos after 24 h incubation calculated for fish of this class.

The results of the investigation of *C. gariepinus* females divided into two classes of body weight ($\bar{x} = 4.89 \pm 0.49$ and $\bar{x} = 6.96 \pm 0.72$), carried out by BRZUSKA (2003a), showed that irrespective of the applied ovulation stimulator (CPH or Aquaspawn) the quality of eggs obtained from fish of higher or lower body weight was similar after both 12 h and 24 h as well as after 28 h incubation. It was found in the experiment with CPH or Lecirelin as ovulation stimulators that irrespective of the applied preparation the percentage of live embryos (after 24 h and 28 h incubation) developing in eggs obtained from females of the higher body weight ($\bar{x} = 3.91 \pm 0.23$ kg) exceeded the percentage of live embryos developing in eggs obtained from females of the lower weight ($\bar{x} = 2.53 \pm 0.36$ kg) (BRZUSKA et al., 2004). After 28 h incubation the quality of eggs yielded by females of the lower body weight ($\bar{x} = 3.8 \pm 0.40$ kg) stimulated with Ovopel was also higher compared with the quality of eggs obtained from females of the higher mean body weight ($\bar{x} = 8.9 \pm 0.7$ kg) as was found by BRZUSKA (2002) in *C. gariepinus*.

An interesting dependence between the body weight of females, the fertilization percentage and the percentage of live embryos was found in this fish species after the application of two most frequently used ovulation stimulators, i.e., CPH and Ovopel. In the case of hypophysation the quality of eggs from females of a higher and lower body weight was very similar while after the treatment with Ovopel the quality of eggs from heavier fish was much poorer (BRZUSKA 2001a).

In an investigation of European catfish *Silurus glanis* the females were divided into two groups of a different mean body weight ($\bar{x} = 5.67$ kg and $\bar{x} = 10.00$ kg); the results showed that after the ovulation stimulation either with CPH or Ovopel eggs of a much poorer quality were obtained from heavier fish both after 24 and 48 and also after 56 h incubation (BRZUSKA 2001b). However, the results of three experiments carried out with this fish species showed that from females of the lower body weight eggs of a better quality were obtained only after the treatment with Ovopel (BRZUSKA 2003b).

The problem of dependence of the quality of eggs obtained from carp *Cyprinus carpio* females of different body weight were studied by CEJKO

(2007). The results reported by the above author contain information that eggs yielded by the heaviest females (body weight above 11 kg) both after hypophysation and Ovopel injection were characterized by the lowest percentage of live embryos after 24 h incubation while a much poorer quality was observed for eggs from hypophysed fish.

In summing-up the results of investigation reported in the presented paper it is possible to state that the highest effectiveness of reproduction characterized the class of females whose body weight exceeded 4.5 kg but did not rise above 6.5 kg. From 100% of females of this class eggs were obtained and their quality was satisfactory both after 12 and 24 h incubation. In this class fish yielded eggs of a mean weight of 495.3 g., this value approximating the general mean of the whole set for this trait. For this class of female body weight the prediction of the percentage of live embryos after 24 h incubation of eggs can be regarded as satisfactory if in the regression equation the independent variables were both the female body weight and the weight of eggs.

The poorest results of the conducted reproduction were obtained for the class of fish of the lowest body weight. In this class the lowest percentage of females spawned and as many as 14.3% of spawning fish gave eggs characterized with the fertilization percentage below 25. In this class of females the lowest mean weight of eggs expressed in grams, deviating from the general mean by as many as –278.7 g was obtained. The prediction of both the percentage of fertilization (12 h) and that of live embryos (24 h) can be evaluated as satisfactory in this class both if in the regression equation the independent variable was only the female body weight and if two independent variables, i.e., the female body weight and the weight of eggs were accepted.

Of the females in the sixth class of body weight, i.e., these of the highest weight, 80% yielded eggs whose quality could be regarded as satisfactory. In this class the highest mean weight of eggs was recorded, however, their quality (expressed as the percentage of fertilization and percentage of live embryos) considerably deviated in minus from the mean for the whole set for these two traits. For this class of fish body weight the prediction of the weight of eggs can be regarded as satisfactory. The prediction of the fertilization percentage and of live embryos can also be regarded as satisfactory both if in the equation the female body weight was taken as an independent variable and if the independent variables were the female body weight and the weight of eggs.

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RECREATIONAL FISHERIES AND FISHING GROUNDS IN THE CONTEXT OF THE TOURIST ATTRACTIVENESS OF LAKELAND REGIONS

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Key words: recreational fisheries, tourism, Lakeland regions, fishing grounds.

Abstract

Recreational fisheries and dynamically growing aquaculture are the leading disciplines in inland fisheries. In addition, recreational fisheries (particularly angling) as an element of recreational, active and specialist tourism, generates important social and economic benefits. In many countries, it constitutes a significant part of the gross national product. Recreational fisheries, as a distinct and attractive tourist product, complements the recreational and tourist offer, especially in regions with abundant water ecosystems. This is particularly evident in the case of the province of Warmia and Mazury, where the qualities of the natural environment and numerous water reservoirs create great potential for fisheries and are a very important component of the activities offered by agritourist farms. This paper also presents a proposed division of fishing grounds for anglers by the author and discusses the role of Fisheries Local Action Groups in the development of recreational fisheries in the province of Warmia and Mazury.

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RYBACTWO REKREACYJNE I ŁOWISKA WĘDKARSKIE W KONTEKŚCIE ATRAKCYJNOŚCI TURYSTYCZNEJ OBSZARÓW POJEZIERNYCH

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Słowa kluczowe: rybactwo rekreacyjne, turystyka, regiony pojezierne, łowiska wędkarskie.

Abstrakt

Rybactwo rekreacyjne (*recreational fisheries*) jako jeden ze sposobów pozyskiwania ryb wraz z dynamicznie rozwijającą się akwakulturą stanowią obecnie wiodące dziedziny rybactwa śródlądowego. Rybactwo rekreacyjne, a w szczególności wędkarstwo, jako element turystyki rekreacyjnej, aktywnej oraz specjalistycznej generuje dodatkowo znaczne korzyści społeczno-ekonomiczne, stanowiąc w wielu krajach istotną część dochodu narodowego. Rybactwo rekreacyjne jako niezależny, atrakcyjny produkt turystyczny stanowi doskonałe uzupełnienie oferty wypoczynkowo-rekreacyjnej, szczególne na obszarach obfitujących w naturalne ekosystemy wodne. Jest to wyraźnie widoczne na terenie województwa warmińsko-mazurskiego, gdzie walory przyrodnicze, a w szczególności liczne zbiorniki wodne niosące możliwość korzystania z istniejących łowisk wędkarskich, stanowią niezwykle ważny element funkcjonowania gospodarstw agroturystycznych. Artykuł zawiera również autorski podział łowisk wędkarskich oraz przybliża rolę Lokalnych Grup Rybackich w rozwoju rybactwa rekreacyjnego w województwie warmińsko-mazurskim.

Introduction

Inland fisheries may be divided and classified in numerous ways depending on the area of operation. The specificity of the fishing industry in Central and Eastern Europe differs from this sector in other regions of Europe and the world to such an extent that European standards (especially in the western and southern part of Europe) do not apply to fisheries in Central Europe. This generates many problems and misunderstandings which become evident in the European legal system, particularly in relation to the support programs addressed to the fishing sector, e.g. from the financial resources of The European Fisheries Fund.

The environmental, cultural and historical background of the fishing industry in Poland and in other Central and East European countries, such as the popularity and long tradition in aquaculture in carp-type ponds and commercial lake fisheries, has led to the specific nomenclature and division of Polish fishing sector. This traditional Slavic classification divides the fisheries into marine and inland fisheries, with the latter being sub-divided into lake,

river and pond categories. Such a division has been presented in some contemporary fishing textbooks (e.g. SZCZERBOWSKI 1981, 2008). Nowadays, due to the rapidly changing conditions and legislation, the fisheries in open (public) waters are distinguished and further divided into fishing zones and aquaculture, i.e. rearing and reproduction of aquatic organisms (CZARKOWSKI et al. 2012a).

It should be noted that the term "inland fisheries" is not identical with "inland fishing". Fishing denotes a narrow notion indicating the harvest of aquatic organisms, whereas fisheries includes other numerous fields of human activities such as aquaculture, controlled reproduction of fish, fish stocking management, active and passive protection of ichthyofauna, water monitoring, etc. As opposed to inland fisheries, the marine sector focuses almost exclusively on fishing.

The Polish legal system distinguishes (within the fishing industry) fisheries and fishing, which is reflected in two separate regulations: The Inland Fisheries Act (Ustawa o rybactwie śródlądowym Dz.U.2009.189.1471 j.t.) and The Fisheries Act which applies to marine fishing (Ustawa o rybołówstwie Dz.U.2004.62.574).

However, the most interesting division of the fishing sector, in the context of tourism and recreation, is related to the commercial and recreational fisheries and, consequently, to the correlation between fisheries and the tourist sector. A special role is attributed to fishing grounds which may attract many tourists in the future.

Materials and Methods

The paper highlights the potential of recreational fisheries in the context of development of lakeland regions based on the example of the province of Warmia and Mazury. The analysis was based on fisheries publications with special attention paid to recreational fisheries and tourism. The study includes the legal regulations on fisheries. A significant proportion of the results were based on local strategic documents relating to the development of tourism and fisheries. The analysis was carried out with factual methodology and general methods of conclusion (induction and deduction).

Results and Discussion

Recreational and commercial fisheries: differences and similarities

Angling is the inherent part of the fishing industry. Despite some anglers attempting to separate it from the fishing sector, the majority of researchers perceive angling as a type of fishing (ARLINGHAUS 2004, COOKE and COWX 2004, ARLINGHAUS et al. 2007, EIFAC 2008, COWX et al. 2010, ENVIRONMENT YUKON 2010, ROGERS et al. 2010, WELCOMME et al. 2010, BEARD et al. 2011). In general, inland fisheries are divided into commercial and recreational fisheries. This division is confirmed by the above-mentioned authors. Some of them present a more detailed classification by dividing the commercial fish catches into industrial and domestic fisheries and the recreational fish catches into angling and non-professional fishing with other equipment. In addition, EIFAC (2008) distinguishes the so-called "fishing for living" which provides an opportunity to satisfy the basic needs of local communities which inhabit areas situated near water reservoirs.

The inclusion of angling and recreational fisheries in the fishing sector is justified by the definitions and legal regulations in Poland. In general, the legal acts refer to so-called "amateur fishing". RADECKI (2011) defines this term in relation to the Article 7 of The Act on Inland Fisheries (Ustawa o rybactwie śródlądowym Dz.U. 2009.189.1471 j.t.) with amendments (Dz.U. 2010 No. 182, item 1228 and No. 200, item 1322) as "harvesting fish with a fishing rod or a crossbow". This author emphasizes the difference in the initial and current edition of the fishing act which, after the amendment, does not refer to "the conditions of rearing, reproduction and catching fish in surface inland waters and amateur fish catching" but to "the conditions of rearing, reproduction and catching fish in surface inland waters" and, therefore, classifies amateur fish catching as one of the methods of using living water resources. According to this lawyer, amateur fish catching is simply fishing. The author moves forward with his legal interpretations and concludes that "angling is neither recreation nor sport", but only one of the ways of using fish resources.

The fish catches in inland open waters in Poland are steadily decreasing. SEREMAK-BULGE (2010) reports that the volume of fish catches reached 20,320 tons (including 17,200 tons of recreational catches) in 2004, 17,410 tons (including 14,800 tons of recreational catches) in 2007 and only app. 16,500 tons (including 14,100 tons of recreational catches) in 2010. The volume of recreational catches constitutes over 86% of the total catches in the fishing zones in Poland. Similar proportions have been observed in some provinces in Canada (Environment Yukon 2010), in Denmark (JACOBSEN et al. 2004) and in Germany (BRÄMICK 2007).

WOŁOS and DRASZKIEWICZ-MIODUSZEWSKA (2011) report the data generated by analysing the volume of angling catches in the selected fish farms, which indicates a high average daily harvest of fish (app. 1.5 kg) per angler. By multiplying these values by the number of sold permits and the surface of fishing waters (as was done by the above-mentioned authors) it may be concluded that the angling catches in Poland constitute app. 260% of professional fish catches.

In Poland, there were only 474 commercial fishermen in inland open waters in 2007. The surface of water per fisherman averaged 817 ha (WOŁOS et al. 2009). With a decreasing tendency, it is assumed that in the near future the surface of water per commercial fisherman would reach app. 1000 ha. In the case of people fishing with rods, the surface of water will be app. 0.35 ha per fishing person.

In order to depict the strong pressure of recreational fisheries on inland waters in Poland, it should be compared with the pressure in Finland, with 1,800,000 recreational anglers per app. 3.300.000 ha of inland waters (KUUSISTO 2012). In Poland, there is a similar number of anglers (i.e. 1,500,000 to 2,000,000 (WOŁOS 2006), but a six-fold smaller water surface. The Polish Angling Association includes almost 620,000 members (KUSTOSZ 2011).

It should be noted that the individual fishing efficacy of anglers is different, depending on the abilities, equipment and, above all, on personal engagement. There are anglers who go fishing a few times a year and there are others who angle almost every day. The latter are sportsmen who, on a daily basis, improve their professional capacities and divide their time between training and angling competitions. The efficacy of such anglers may be very high, amounting to a number of tons per year (SAMET: oral report). The total volume of fish catches is not intended for consumption, but anonymous interviews with anglers confirm very high catches, particularly of predatory species such as pike (in this case, the number of fish caught may amount to few hundred per angler per year).

The goal of fishing, not the tool that is used, makes an angler a "recreational fisherman". If a fisherman wants to bring fish to the market for general consumption and gain profit in this way, he then becomes a commercial fisherman. However, if a fisherman seeks recreation, adventure and excitement and also wants to consume fish (without putting it on the market), he becomes a recreational fisherman.

In modern society, the role of both types of fisheries is different. Commercial fishermen have a special mission since their role is to provide society with access to high-quality food. Nowadays, the commercial fish catches in inland waters constitute a tiny fraction of the total fish production, because aquaculture becomes the leading producer and commercial fisheries in open inland waters are, in reality, a traditional addition. The most recent data indicates

a further decrease in inland commercial fish catches in Poland, which amount to 6.5% of freshwater fish production and the rest, i.e. 93.5% (app. 30,000 tons), is covered by aquaculture. This situation is comparable in all countries and aquaculture is the most dynamically developing branch of the global food industry.

The recreational fisheries (mainly angling), not the commercial sector, are the biggest hazard to freshwater fish populations. COOKE and COWX (2004), EIFAC 2008, WELCOMME et al. (2010) and Environment Yukon (2010), DONALDSON et al. (2011) have discussed the potential impact of recreational fisheries on the over-exploitation of numerous fish populations.

It should be noted that there is a reasonable and non-confrontational way of solving disputes between recreational and professional fishermen. Both groups have an equal right to use fish resources. In a document entitled, "The Code of Practice for Recreational Fishing", the EIFAC (2008) discerns the conflict between these two communities and recommends minimizing the tension between anglers and professional fishermen and managing the sector and live water resources in a way to ensure sustainable usage for all users.

Recreational fisheries and tourism in lakeland regions

The vast sector of the national industry, i.e. tourism and recreation, is associated with fisheries, in particular with recreational fisheries. The European tourist industry, which includes app. 1.8 million enterprises and employs 5.2% of the total workforce (app. 9.7 million jobs), constitutes over 5% of the EU gross domestic product. If the related sectors are included, the estimated share of tourism in the EU gross domestic product is significantly higher. Tourism indirectly generates over 10% of the EU gross domestic product and creates over 12% of work places (Europe, the world's No. 1 tourist destination...). Recreational fisheries, particularly angling, as a distinct product of recreational, active and specialist tourism, make up a substantial share. It is estimated that angling in Europe generates a total income of app. 25 billion Euros per year (*The Socio-Economic Value*...). In Poland, the angling sector employs app. 15 thousand workers and its total estimated annual value amounts to 1.12 billion PLN (PZW Report 2003).

Tourism, including angling, is a major branch of industry and a basic source of income for local communities in many poorly-industrialized regions of the world. The social and economic benefits that are associated with fisheries are under-exploited in Poland. They create considerable potential for development of Lakeland regions which, apart from their natural values, have a poorly developed infrastructure and high levels of unemployment compared with the national average (KUPREN et al. 2012).

The province of Warmia and Mazury, which covers the majority of the Mazurian Lake District, serves as a good example. The region of Warmia and Mazury is one of the largest European areas, with attractive resources and spectacular natural values, but with low tourism intensity. This region is not a well-established brand on the tourist market, although this can be achieved with development and promotion of specific tourist products. The Strategy for Development of Tourism in Warmia and Mazury (Strategia rozwoju turystyki...) enumerates many possibilities which include actions aimed at using angling resources. A detailed answer to this question is found in a different document on regional development, i.e. Strategy for Development of Fisheries in Warmia and Mazury until 2030 (Strategia rozwoju rybactwa...). According to the authors of this publication, the changes aimed at improving the infrastructure necessary for productive angling and adverse fish inventory are critical, apart from a more expansive promotion of angling values. The main causes of disruption of the ichthyofauna structure include:

– the process of eutrophication of ichthyofauna;
– violation of regulations on shore protection;
– increasing the size of the cormorant population;
– insufficient input for fish stocking with species preferred by anglers;
– insufficient expenditure on the protection and monitoring of ecosystems.

In the case of angling infrastructure, the main area of interest is the availability of fishing areas and hotel accommodation.

Rural tourism, including agritourism, is one of the numerous forms of tourism and it is dynamically developing in Lakeland regions. The data presented by CZARKOWSKI et al. (2012b) confirms the clear impact of natural waters and angling grounds on the condition and development of rural tourism in the province of Warmia and Mazury. The authors emphasize that 90% of agritourist holdings are situated in lake districts (counties) and 65% (452) of the farms presented in the Catalogue of Agritourist Farms entitled "The Countryside of Warmia and Mazury Invites You" (KOGUT and KAPELEWSKA 2010) offer recreational fisheries as one of the local attractions. As only 80 of these farms have their own fish ponds, the majority of agritourist holdings use the abundance of natural, mainly lake, fishing grounds.

Fisheries Local Action Groups and the development of recreational fisheries and fishing grounds

In the province of Warmia and Mazury, the opportunity for angling with an accommodation background is offered mainly by agritourist farms. In recent years, this type of accommodation has become a predominant and rapidly

developing type of hotel (Strategy for Development of Tourism in Warmia and Mazury). The fishing lake farms have significantly contributed to this developmental potential (Strategy for Development of Fisheries in Warmia and Mazury until 2030). The development of infrastructure associated with recreational fisheries is supported with the availability of EU funds. The European Fisheries Fund 2007–2013 (EU Regulation No 1198/2006 of July 27, 2006) provides a high level of assistance. This fund guarantees many years of co-funding of the activities detailed in The Strategy for Development of Fishing 2007 and in the Operational Programme, "Sustainable Development of the Fisheries Sector and Coastal Fishing Areas 2007–2013" (OP "Fish").

The measures aimed at sustainable development of regions which depend on fisheries (313 million Euros, i.e. 32% of financial resources of the whole OP "Fish") are the main points of the Programme. This is to be achieved through mobilization of communities which depend on fisheries (including Lakeland regions) with the inclusion of social and industrial partners in the planning and implementation of local initiatives. Currently, this strategy is being put into effect within the framework of the Local Strategies of Development of Fishing Regions by the Fisheries Local Action Groups (48 in Poland and 4 in Warmia and Mazury). The main goal of Local Strategies for Development of Fishing Regions is to improve the living conditions in areas which depend on fisheries through development of entrepreneurship and initiatives within local communities as well as support of development of infrastructure largely designed for anglers (KUPREN et al. 2012).

General and specialist fishing grounds

Finally, this contribution tries to specify the notion of a "fishing ground", as the main and inherent component of angling infrastructure. The term is defined as a site designed for fishing. The recently published "Encyclopaedia of Fisheries" edited by Prof. SZCZERBOWSKI (2011) lacks such an entry as "fishing ground" and its description. However, logically, the fishing ground is a place for catching fish with angling methods (with a fishing rod) by people called "anglers" and for amateur purposes.

The fishing grounds may be divided into general operating grounds and specialist grounds. According to the above-cited encyclopaedia (*Encyklopedia rybactwa* 2011), "special fishing grounds" are "water reservoirs and sectioned part of water flows destined for amateur fish catching. They may include typical fish ponds seasonally available for anglers as well as recreational water reservoirs stocked with well-grown fish. As opposed to ordinary fishing areas, a specialist fishing area is usually separated, i.e. fenced and monitored".

It seems that this definition should be complemented with one characteristic element: angling in the so-called special fishing grounds (regardless of the type of ground) is always associated with an extra fare. The use of a special fishing area, regardless of the fact that a person pays for each caught fish in a fish pond or for purchasing a supplementary permit for special lake area, always requires an extra fare for angling and is more expensive than angling in general fishing areas. This is logical, since these types of fishing grounds are created for commercial purposes and for generating income. Even if such fishing areas are set up for social reasons by a Local Fishery Action Groups, the costs of its maintenance will necessitate higher fares for angling.

CZERWIŃSKI et al. (2006) divided special fishing grounds into pond, lake and river categories and proposed a more detailed classification which included the legal division of waters (ownership rights) and the main rules of fishing use (Figure 1).

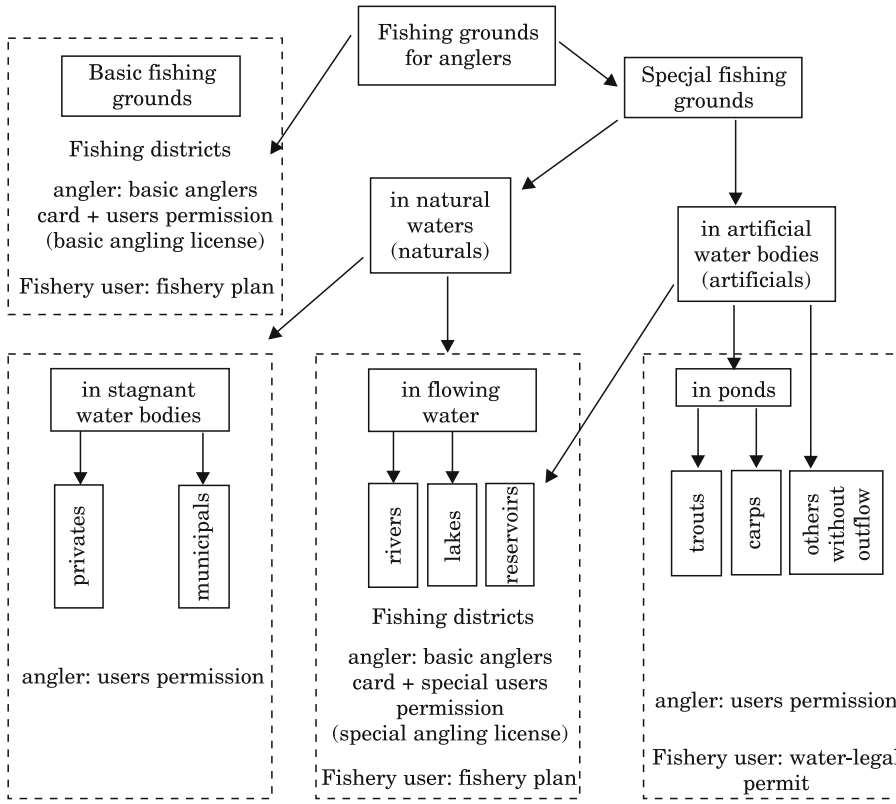

Fig. 1. The division of fishing grounds based on the legal division of waters (ownership rights) and the main ways of usage

Despite the fact that special fishing grounds do not generate as much interest as 10–15 years ago, they may still be a tourist and angling attraction, especially in relation to agritourism. The small "put and take" fishing grounds seem to be the key to success since they may operate on every agritourist farm (even in those located near lakes). Many tourists are not well-experienced anglers who can easily handle wild fish on large waters and they therefore need a "practice session" on a small reservoir with dense fish stocking where, supervised by a professional, they can learn to entice, bait a hook, tow and take off fish, etc.

Conclusions

Recreational fisheries, mainly angling, are one of the leading disciplines in inland fisheries. It is undoubtedly a very important element of the tourist offer, including rural tourism, in lakeland regions. This is particularly evident in the case of the province of Warmia and Mazury, where the qualities of the natural environment facilitate the use of fishing grounds, which are a very important component of tourism. It seems that further development of fisheries, not limited to recreational fisheries, may influence the intensity of tourism and form the core of rural tourism and agritourism in lakeland regions. This goal may be supported by European financial resources, e.g. from The Operational Programme "FISH" 2007–2013, and the so-called "Fisheries Local Action Groups" set up with the assistance of these funds.

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IMPACT OF CONDITIONS OF RAPESEED OIL HYDRATION ON THE CONTENT AND PROFILE OF PHOSPHOLIPIDS

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K e y w o r d s: rapeseed oil, hydration, hydrated oil, oil gums, phosphorus content, phospholipids content, profile of phospholipid fraction.

A b s t r a c t

The aim of the study was to determine the impact of hydration conditions on the content of phosphorus and the content and profile of phospholipids in hydrated oils and oil gums. The experiment was carried out on industrial hot-pressed oil which was subjected to hydration reaction with different additions of water (0.5, 1.5 and 3.0%) and at different temperatures (70 and 80°C). The following parameters were determined: content of phosphorus in accordance with PN-88/A-86930 (*Tłuszcze roślinne jadalne*... PN-88/A-86930), lipid composition with column chromatography and profiles of the phospholipid fraction with thin layer chromatography. The content of phosphorus, profile of phospholipids and composition of fatty acids were measured in oil gums extracted in the hydration process.

It was found that the content and profile of phospholipids in hydrated oils significantly depended on the conditions during hydration and the dose of water was a more differentiating factor than the temperature of the hydration reaction. The greatest degree of phospholipid removal was recorded during hydration of oil with 0.5% water at 70°C. The oils hydrated with 3.0% water at both temperatures showed the lowest degree of phospholipid removal and the extracted oil gums had the lowest content of phosphorus and noticeable residues of oil. The impact of hydration conditions on the profiles of phospholipids in hydrated oils, oil gums and the composition of fatty acids was minimal. Phosphatidylcholine and phosphatidylinositol were the most hydratable phospholipids because of the highest degree of their removal during hydration.

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WPŁYW WARUNKÓW HYDRATACJI NA ZAWARTOŚĆ FOSFORU I UDZIAŁ FOSFOLIPIDÓW W OLEJACH RZEPAKOWYCH I ŚLUZACH POHYDRATACYJNYCH

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S ł o w a k l u c z o w e: olej rzepakowy, hydratacja, olej hydratowany, śluzy, zawartość fosforu, udział fosfolipidów, profil fosfolipidowy, skład kwasów tłuszczowych.

A b s t r a k t

Celem badań było określenie wpływu warunków hydratacji na zawartość fosforu oraz udziału i profilu fosfolipidów w olejach hydratowanych laboratoryjnie i otrzymanych śluzach. Badano przemysłowy olej tłoczony na gorąco poddany hydratacji różnymi dodatkami wody (0,5, 1,5 i 3,0%). Proces prowadzono w temperaturach 70 i 80°C. W olejach określono: zawartość fosforu – metodą wg PN-88/A-86930, (*Tłuszcze roślinne jadalne...* PN-88/A-86930) skład lipidowy – metodą chromatografii kolumnowej oraz profile fosfolipidowe – metodą chromatografii cienkowarstwowej. W śluzach pohydratacyjnych oznaczono zawartość fosforu, profil fosfolipidowy oraz skład kwasów tłuszczowych.

Stwierdzono, iż udział i profil fosfolipidów olejów hydratowanych istotnie zależał od warunków hydratacji, przy czym dawka wody była bardziej różnicującym czynnikiem niż temperatura hydratacji. Największy stopień usunięcia fosforu uzyskano, prowadząc hydratację 0,5% dodatkiem wody w temperaturze 70°C. Oleje hydratowane 3,0% dodatkiem wody w obu temperaturach hydratacji cechowały się najwyższą zawartością fosforu i udziałem fosfolipidów, a śluzy z nich wydzielone – najniższą zawartością fosforu. W dwuczynnikowej analizie wariancji wykazano, iż przyjęte warunki hydratacji miały różny wpływ, aczkolwiek niższy, na kształt profili fosfolipidowych oraz skład kwasów tłuszczowych niż na stopień usunięcia fosforu. Hydratacja w największym stopniu usunęła fosfatydylocholinę i fosfatydyloinozytol, co świadczy o ich przynależności do fosfolipidów hydratowalnych.

Introduction

Crude rapeseed oil is mainly composed of triacylglycerols and minor amounts of non-triacylglycerol compounds such as phospholipids, free fatty acids, sterols, tocopherols, pigments, flavonoids and glycolipids. Phospholipids generate many technological problems during the production of rapeseed oil and therefore they should be removed to the highest degree possible (SZYDŁOWSKA-CZERNIAK 2007).

During processing of rape seeds and oil pressing, phospholipids are released due to physical, thermal or enzymatic degradation of membranes and they freely migrate to extracted oil (PRIOR et al. 1991, NIEWIADOMSKI 1993, SZWED and TYS 1995a,b). Oils with a high content of phospholipids are turbid, with worse colour, taste and smell and have a shorter shelf-life (SIMPSON 1991, SUBRAMANIAN et al. 1999, HAFIDI et al. 2005, KORIS and MARKI 2006, YANG et al. 2006). A higher content of phosphorus in oils subjected to acid degumming

impairs the course of further refining processes and/or oil modification (UNGER 1990, SUBRAMANIAN and NAKAJIMA 1997, JERZEWSKA et al. 2001, VAN GERPEN 2005, PŁATEK 2009).

From a technological point of view, phospholipids (PL) are divided into hydratable (HF) and non-hydratable (NHF) compounds. Phospholipids such as PC, PI and lysoPL are easily hydratable. PE is partially hydratable, whereas PA is classified as non-hydratable (SUBRAMANIAN et al. 1999, ZUFAROV et al. 2009). Free PA is created as a result of phospholipase D activity but, due to the presence of free metal ions (calcium and magnesium) in oils, it forms non-hydratable salts with them. Two-phase degumming is commonly implemented in industry, with preliminary degumming (water degumming, hydration) is carried out in an extracting facility and primarily relates to extracting oil immediately after solvent evaporation. Such extracted oil is mixed with raw pressed oil and then it constitutes crude oil for the refining process which, according to PN-87/A-86906 (*Tłuszcze roślinne jadalne...* PN-87/A-86906), may contain up to 200 ppm phosphorus. The so-called "terminal degumming" is the first stage of oil refining process and consists of removing non-hydratable phospholipids with the use of mineral or organic acids (NIEWIADOMSKI 1993, PRZYBYLSKI et al. 2005). The parameters of hydration presented in the literature are ambiguous: the doses of water reported by authors range from 0.5 to 5.0% and the temperature of hydration is between 70 and 90°C (ALY 1991, INDIRA et al. 2000, ESHRATABADI et al. 2008, ZUFAROV et al. 2008). Few publications have discussed the impact of hydration conditions on the content and profile of phospholipids in oils and oil gums and the composition of fatty acids.

It was therefore assumed to determine the impact of hydration conditions on the content and profile of phospholipids in oils and extracted oil gums.

Materials and Methods

Description of study material

The study was carried out on a sample of industrial hot-pressed rapeseed oil that originated from Oleochemical Plant BIELMAR in Bielsko-Biała, Poland. The oil was extracted from seed mash conditioned at 110–112°C for 30 minutes and then pressed at 110–120°C.

Hydration of oils

Redistilled water at 0.5, 1.5 and 3.0% in relation to a weighted portion of oil was added to oil heated to 70/80°C and the hydration process was then carried out for 15 minutes. Hydration was performed on electromagnetic stirrers (rotation velocity = 250 rpm) with a constant sample temperature. Post-hydration gums were removed from oil by centrifuging (10 min/1000 rpm).

Methods

The phosphorus content (*Tłuszcze roslinne jadalne*... PN-88/A-86930), the composition of lipids with column chromatography (OHM and CHUNG 1999) and the profiles of phospholipids with thin layer chromatography (NAZI and PROCTOR 1998) were determined.

Determination of lipid composition in oils. The measurement was carried out in MEGA BOND SI 1GM 6ML columns. The flow of solvent through the columns was forced at a negative pressure of 18 kPa in a BAKER SPE-12 G chamber. In the first stage, the column was conditioned with 5 ml chloroform. The sample was prepared by dissolving the extract of lipids in 25 ml of chloroform and then, depending on the sample, 10 ml of such solution was placed on a column. Lipids were fractionated by gradual washing with proper solvents. Fractions of non-polar lipids (NPL) were washed away with 10 ml chloroform: acetone mixture (4:1), glycolipids (GL) with 15 ml acetone: methanol mixture (9:1) and phospholipids (PL) with 10 ml methanol. Following fractioning, the solvents were evaporated in a VI-PAR-type 350 vacuum evaporator at 50°C and lower pressure and the samples were then weighed.

Determination of phospholipid profiles. The measurements were carried out on 20 x 20 cm MERCK chromatographic plates with silica gel. The plates were conditioned in a drier at 105°C for 1 h. The chromatographic chamber was saturated with a mixture of solvents (chloroform: methanol: water = 75: 25: 3). The previously-extracted phospholipid fractions and phospholipid SIGMA standards (phosphatidylcholine, phosphatidylethanolamine, phosphatidylinositol, phosphatidylserine, lysophosphatidylcholine, phosphatidic acid) weighing app. 25 μg were placed on the plates. The plates were then put into a chromatographic chamber and the chromatograms were stained in iodine atmosphere and then scanned in order to process the results. Treatment of the results was carried out using a densitometry method, involving the measurement of the intensity of spots using the TLC Chromatograf v 1.0 program.

The extracted oil gums were characterized by measuring the content of phosphorus with the method described above, the profiles of phospholipids (as described above) and composition of fatty acids (*Analiza estrów metylowych*... PN-EN ISO 5508:1996) by preparing methyl esters according to ZADERNOWSKI and SOSULSKI (1978). The separation of methyl esters was performed with GC 8000 series, FISONS Instrument, gas chromatograph with the use of flame ionization detector and a packed-column type-DB-225 (30 m x 0.25 mm) filled with chromosorb GP. Helium was the carrier gas. Fatty acids were identified based on retention times determined for standards.

The oil gums extracted from hydrated oils were photographed with an array for digital image analysis that included a Nikon DXM 1200 digital camera, a KAISER RB HF light source (consisting of 4 fluorescent 36W lamps with a colour temperature of 5400°K), a computer with an image acquisition card compatible with a DXM 1200 digital camera, LUCIA G Wer. 4.80 software, a computer display and a printer (TAŃSKA 2005).

Statistical analysis

The results of the study were statistically analysed with Statictica 9.0 PL software (StatSoft Poland). One-way analysis of variance (ANOVA), together with Tukey's test with a critical significance level at $p=0.05$ were performed to find the significance of differences between the oil samples. The impact strength of tested factors on the content of phosphorus, content and profile of phospholipids and composition of fatty acids was determined with a two-way analysis of variance.

Results

The content of phosphorus in the tested oil was 209.9 mg kg^{-1} (Table 1). Hydration of this oil carried out at both temperatures with 0.5 and 1.5% water resulted in a similar degree of phospholipid removal (> 70%). The lowest efficacy was reported during the hydration process with 3.0% water when the degree of phospholipid removal was only 11.2% (70°C) and 13.1% (80°C) – Table 1.

The content of phosphorus in the extracted oil gums in the conditions of hydration of oils was significantly diversified (Table 1). The highest content of phosphorus was detected in the oil gums extracted during oil hydration with 0.5% water, while the lowest content was with 3.0% water (Table 1). The diversification of oil gum parameters is seen in the photographs (Figure 1). The photographs taken on a light background indicate the colour of oil gum fractions, whereas on a dark background they reveal the structure of oil gums

Table 1

Content of phosphorus [mg kg^{-1}] in hydrated oils and post-hydration oil gums

Conditions of hydratation	Hydrated oils		Post-hydration oil gums
	content of phosphorus [mg kg^{-1}]	degree of removal of phospholipids [%]	content of phosphorus [mg kg^{-1}]
Crude oil	$209.9^{d} \pm 6.88$	–	–
70°C/0.5%	$53.6^{a} \pm 0.62$	74.5	$13982^{d} \pm 68$
70°C/1.5%	$61.1^{b} \pm 1.56$	71.4	$8129^{b} \pm 34$
70°C/3.0%	$186.4^{c} \pm 4.02$	11.2	$5051^{a} \pm 50$
80°C/0.5%	$55.8^{a} \pm 0.97$	73.4	$12013^{c} \pm 90$
80°C/1.5%	$58.3^{ab} \pm 1.18$	72.2	$8802^{b} \pm 81$
80°C/3.0%	$182.4^{c} \pm 1.32$	13.1	$5120^{a} \pm 40$

a,b... – mean values in columns marked with the same letter are not significantly different ($p \leq 0.05$)

placed on a thin layer. Because of the close similarity between the photographs of oil gums taken at both hydration temperatures, only the images of oil gums taken at 80°C are presented in this publication (Figure 1). The oil gums extracted from hydrated oil with the lowest dose of water (0.5%) were darker (Figure 1a) than the oil gums formed during hydration with higher water doses, which had a lighter colour due to oil residues (Figure 1c, 1e). The structure of oil gums extracted with 0.5% water was more compact (Figure 1b) than the texture of oil gums extracted with 1.5 and 3.0% water (Figure 1d, 1f).

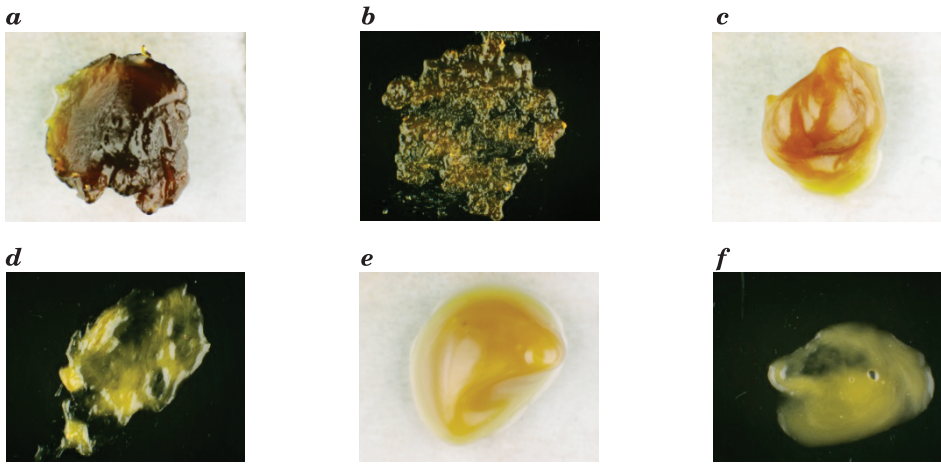

Fig. 1. Oil gums extracted during hydration of oil at 80°C with different water doses; where: *a, b* – 0.5% water, *c, d* – 1.5% water, *e, f* – 3.0% water

Non-polar lipids were predominant in the composition of initial oil and the content of phospholipids was 0.73% (Table 2). The oils hydrated with different doses of water had a lower content of phospholipids. The oil hydrated with 0.5% water had the lowest concentration of phospholipids (0.27% at 70°C and 0.30% at 80°C) which indicated the largest degree of their removal. Together with the increase in water doses, the efficacy of hydration process decreased – which was confirmed by the higher content of phospholipids in the oils (Table 2).

The profile of phospholipids in raw oil consisted of PC, PI, PE and PA. The most evident changes during oil hydration were reported in the content of PE which increased from 21.88% (non-hydrated oil) to 64.22% in the oil hydrated with 0.5% water at 70°C (Table 2). The content of PI decreased from 29.13% to 11–15%, except for the oil hydrated at 70°C with 0.5% water in which it amounted to 4.37%. The concentration of PC in the hydrated oils was lower than in the initial oil. The impact of varied water doses was noted only in the case of oils hydrated at 70°C, in which the content of PC ranged from 18.62% in the oil hydrated with 0.5% water to 30.92% in the oil hydrated with 3.0% water. The concentration of PA remained virtually unchanged in all oils hydrated at 80°C and it was increased only in the oils hydrated at 70°C with lower (0.5 and 1.5%) doses of water (Table 2).

Three phospholipids (PC, PI and PE) were detected in post-hydration oil gums (Table 2). PC was the predominant phospholipid and its content in all samples of oil gums, regardless of hydration conditions, ranged between 49.01 and 52.57%. PE was the second-most abundant phospholipid and its content ranged from 24.57% to 30.15% in the oil gums formed following hydration with 1.5% water at 80°C and 70°C. The other samples of oil gums were not varied in their PE content (Table 2). The concentration of PI in the majority of oil gum samples was not statistically different (Table 2). The shape of phospholipid profiles in the oil gums, whose PC and PI concentrations were significantly higher and PE content was much lower than in the hydrated oils, confirms that PC and PI are hydratable phospholipids, while PE is classified as a non-hydratable phospholipid.

The composition of fatty acids in the initial oils was typical of rapeseed oil (Table 3). The samples of oil gums obtained under different hydration conditions differed significantly in the content of fatty acids in comparison with the initial oil. In general, it was found that the hydrated oils had a lower content of oleic acid (54–57% vs. 62.34%) and linolenic acid (6–8% vs. 9.34%), whereas the concentrations of linoleic (24–28% vs. 19.67%) and palimitic (8–10% vs. 4.97%) acids were higher (Table 3).

Table 2

Composition of lipid fraction and profiles of the phospholipid fraction of hydrated oils and post-hydrated oil gums

Conditions of hydratation	Hydrated oils							Post-hydrated oil gums		
	lipid composition [%]			phospholipid profile [%]				phospholipid profile [%]		
	NPL	GL	FL	PC	PI	PE	PA	PC	PE	PI
Crude oil	$98.86^{a*} \pm 0.06$	$0.42^{c} \pm 0.07$	$0.73^{d} \pm 0.02$	$39.83^{d} \pm 0.68$	$29.13^{e} \pm 1.13$	$21.88^{a} \pm 0.79$	$8.47^{abc} \pm 0.75$	–	–	–
70°C/0.5%	$99.39^{c} \pm 0.01$	$0.34^{a} \pm 0.03$	$0.27^{a} \pm 0.01$	$18.62^{a} \pm 0.38$	$4.37^{a} \pm 0.08$	$64.22^{d} \pm 0.59$	$12.79^{d} \pm 1.05$	$49.01^{a} \pm 0.27$	$27.71^{ab} \pm 1.02$	$23.29^{bc} \pm 0.77$
70°C/1.5%	$99.32^{b} \pm 0.01$	$0.31^{ab} \pm 0.04$	$0.37^{b} \pm 0.03$	$24.16^{b} \pm 1.96$	$15.37^{d} \pm 0.18$	$47.58^{bc} \pm 1.24$	$12.94^{d} \pm 0.91$	$49.24^{ab} \pm 2.21$	$30.13^{b} \pm 3.39$	$20.63^{ab} \pm 1.24$
70°C/3.0%	$98.99^{a} \pm 0.05$	$0.35^{a} \pm 0.05$	$0.67^{c} \pm 0.01$	$30.92^{c} \pm 0.88$	$14.75^{cd} \pm 1.06$	$47.13^{b} \pm 0.11$	$7.19^{a} \pm 0.29$	$51.72^{ab} \pm 0.46$	$29.35^{ab} \pm 0.94$	$20.69^{ab} \pm 2.03$
80°C/0.5%	$99.45^{c} \pm 0.05$	$0.25^{a} \pm 0.01$	$0.30^{a} \pm 0.02$	$28.23^{ab} \pm 1.31$	$12.82^{bc} \pm 0.26$	$49.03^{bc} \pm 1.37$	$9.92^{c} \pm 0.33$	$50.76^{ab} \pm 1.96$	$25.20^{ab} \pm 2.36$	$24.48^{c} \pm 0.24$
80°C/1.5%	$99.40^{b} \pm 0.03$	$0.26^{ab} \pm 0.04$	$0.33^{b} \pm 0.01$	$27.93^{bc} \pm 1.29$	$11.94^{b} \pm 0.93$	$50.90^{bc} \pm 2.40$	$9.23^{bc} \pm 0.18$	$52.57^{b} \pm 0.36$	$24.57^{a} \pm 0.92$	$22.87^{bc} \pm 1.23$
80°C/3.0%	$98.86^{a} \pm 0.09$	$0.49^{bc} \pm 0.09$	$0.65^{c} \pm 0.01$	$29.92^{c} \pm 1.60$	$10.94^{b} \pm 0.66$	$51.45^{c} \pm 1.54$	$7.68^{ab} \pm 0.72$	$51.56^{ab} \pm 0.51$	$29.08^{ab} \pm 1.17$	$19.36^{a} \pm 1.31$

a,b... – mean values in columns marked with the same letter are not significantly different ($p \leq 0.05$)

Table 3

Fatty acid composition of post-hydrated oil gums

Conditions of hydratation	Fatty acid [%]					
	$C_{16:0}$	$C_{18:0}$	$C_{18:1}$	$C_{18:2}$	$C_{18:3}$	
Crude oil	$4.97^{a} \pm 0.07$	$1.52^{c} \pm 0.01$	$62.34^{c} \pm 0.01$	$19.67^{a} \pm 0.04$	$9.34^{e} \pm 0.05$	2.14 ± 0.18
70°C/0.5%	$8.72^{b} \pm 0.59$	$1.19^{a} \pm 0.06$	$56.94^{b} \pm 0.03$	$26.46^{c} \pm 0.69$	$6.69^{c} \pm 0.07$	trace
70°C/1.5%	$8.25^{b} \pm 0.70$	$1.14^{a} \pm 0.06$	$57.22^{b} \pm 0.91$	$26.91^{cd} \pm 0.05$	$6.48^{bc} \pm 0.11$	trace
70°C/3.0%	$10.15^{c} \pm 0.45$	$1.63^{d} \pm 0.06$	$54.61^{a} \pm 0.95$	$27.53^{d} \pm 0.06$	$6.08^{ab} \pm 0.50$	trace
80°C/0.5%	$8.45^{b} \pm 0.10$	$1.91^{e} \pm 0.18$	$57.37^{b} \pm 0.08$	$24.43^{b} \pm 0.42$	$7.84^{d} \pm 0.06$	trace
80°C/1.5%	$9.12^{bc} \pm 0.47$	$1.38^{b} \pm 0.05$	$57.11^{b} \pm 0.28$	$26.55^{c} \pm 0.54$	$5.84^{a} \pm 0.30$	trace
80°C/3.0%	$10.08^{c} \pm 0.72$	$1.28^{ab} \pm 0.04$	$55.37^{a} \pm 0.81$	$27.52^{d} \pm 0.18$	$5.75^{a} \pm 0.05$	trace

a,b... – mean values in columns marked with the same letter are not significantly different ($p \leq 0.05$)

Table 4

Coefficients of significance (*F*) determined with two-way analysis of variance for hydrated oils and post-hydration oil gums

Discriminant		Factor of variance		
		hydration temperature	addition of water	hydration temperature x addition of water
Hydrated oils	content of phosphorus [mg kg^{-1}]	6*	16867**	8**
	share of phospholipids [%]	7*	2313**	20**
	share of PC in phospholipid fraction [%]	87**	85**	47**
	share of PI in phospholipid fraction [%]	n.s.	209**	344**
	share of PE in phospholipid fraction [%]	25**	105**	187**
	share of PA in phospholipid fraction [%]	97**	146**	25**
Post-hydration oil gums	content of phosphorus [mg kg^{-1}]	361**	45236**	1375**
	share of PC in phospholipid fraction [%]	n.s.	8*	n.s.
	share of PE in phospholipid fraction [%]	10**	n.s.	n.s.
	share of PI in phospholipid fraction [%]	n.s.	14**	n.s.
	share of stearic acid [%]	n.s.	29**	n.s.
	share of palmitic acid [%]	44**	34**	106**
	share of oleic acid [%]	n.s.	45**	n.s.
	share of linoleic acid [%]	35**	81**	21**
	share of linolenic acid [%]	n.s.	104**	45**

* – significant impact of factor at $p \leq 0.05$
** – significant impact of factor at $p \leq 0.01$
n.s. – not significant

Statistical analysis. A two-way analysis of variance revealed that the content of phosphorus in oils (F=16867) and oil gums (F=45236) depended to the largest extent on the amount of water used for hydration and the relationship between this factor and hydration temperature (F=1375). The impact of hydration temperature on the concentration of phosphorus in the hydrated oils (F=6) and oil gums (F=361) was minimal (Table 4). The content of phospholipid fraction in the hydrated oils depended more on a water dose (F=2313) than hydration temperature (F=7) (Table 4). In addition, the two-way analysis of variance showed that the impact of hydration condition on the shape of phospholipid profiles in hydrated oils and oil gums was minimal, which was further confirmed by the values of coefficient significance: F=25–209 for oils and F=10–104 for oil gums (Table 4).

Discussion

The analysis of the impact of hydration conditions of rapeseed oil (70/80°C x 0.5; 1.5; 3.0% water) showed that the degree of phospholipid removal decreased with an increase in water. The best results were achieved when the hydration process was performed with 0.5% water at 70°C. The oil hydrated under these conditions had the lowest content of total phosphorus and the lowest concentration of phospholipids and the extracted oils gums contained the highest amount of phosphorus. INDIRA et al. (2000) carried our hydration of rice oil, which contained 1.8% phospholipids, with varied water doses (0.5–4.0%) and at different temperatures (26–90°C) and found that the optimal performance of the process was effectuated with 4.0% water at 68–73°C. Hydration under these conditions yielded the highest (80%) degree of removal of phospholipids. The results of the above cited publication differ from our studies in which higher doses of water (1.5%, 3.0%) reduced the amount of extracted phosphorus. It was also found that the oils hydrated with 3.0% water were turbid following centrifugation and water droplets were visible after resting. The extracted oil gums had a looser, oily texture and a lighter colour, which might be related to the increased content of oil and water droplets (Fig. 1). PŁATEK (1998) reported that the amount of water supplied in the hydration process should approximate the percentage of phospholipids. An insufficient amount of water results in incomplete hydration, whereas its excessive volume generates the formation of a 3-phase system consisting of water, oil gums and turbid oil. INDIRA et al. (2000) reported after List et al. that extracted oil gums may undergo re-hydration and be reintroduced into oil phase, especially during long-lasting stirring. ESHRATABADI et al. (2008) reported that the

dose of water used in degumming of crude vegetable oils should be experimentally determined.

SOSADA et al. (2003) analysed the composition of industrial rapeseed lecithin and showed that it contained 63% of substances which were non-soluble in acetone, including 15% PC, 25% PE, 35% PI and other compounds such as lysophospholipids, glycolipids, sterols and carbohydrates. VAN NIEUWENHUYZEN and MABEL (2008) examined the composition of liquid rapeseed lecithin and reported that PC was the predominant phospholipid and it amounted to 17%, whereas PI, PE and PA constituted 10, 9 and 4% of lecithin, respectively.

Conclusions

1. The content and profile of phospholipids in hydrated oils significantly depended on hydration conditions and the dose of water was a more differentiating factor than hydration temperature.
2. The most effective oil hydration was carried out with 0.5% water at 70°C since it reduced the content of phospholipids to the highest degree.
3. The oils hydrated with 3.0% water at both temperatures had the lowest degree of phospholipid removal and the extracted oil gums had the lowest content of phosphorus and visible oil residues.
4. The impact of hydration conditions on the shape of phospholipid profiles in hydrated oils and oil gums and on the composition of fatty acids was minimal.
5. Phosphatidylcholine and phosphatidylinositol were the most hydratable phospholipids because of the highest degree of their removal during hydration.

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SOCIO-DEMOGRAPHIC DETERMINANTS OF FAST FOOD EATING AMONG THE STUDENTS OF THE UNIVERSITY OF WARMIA AND MAZURY IN OLSZTYN

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Key words: fast food, eating, students.

Abstract

The research showed that about 22% of participants ate fast food at least once a week and 73% consumed it occasionally. More men than women were frequent fast food eaters while opposite relationship was observed among occasional consumers. Almost third of respondents used this food because they didn't have time to prepare meals themselves. The large group (24.3%) admitted that they like the taste of fast foods. Price was the most often indicated factor that determined the choice of fast food. The most often purchased food was pizza closely followed by toasted baguette with vegetables/meat/cheese. Majority of participants expressed an opinion that fast food consumption is unfavourable for health.

CZYNNIKI SOCJODEMOGRAFICZNE WPŁYWAJĄCE NA SPOŻYCIE ŻYWNOŚCI TYPU FAST-FOOD PRZEZ STUDENTÓW UNIWERSYTETU WARMIŃSKO-MAZURSKIEGO W OLSZTYNIE

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Słowa kluczowe: żywność typu fast-food, spożycie, studenci.

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Abstrakt

W badaniach wykazano, że około 22% ankietowanych jadało żywność typu fast-food przynajmniej raz w tygodniu, a 73% sięgało po nią okazjonalnie. Więcej mężczyzn niż kobiet spożywało taką żywność często, podczas gdy odwrotną zależność odnotowano wśród konsumentów jadających ją okazjonalnie. Prawie jedna trzecia respondentów korzystała z takiej żywności ze względu na brak czasu na samodzielne przygotowanie posiłku. Znacząca grupa ankietowanych (24,3%) przyznała, że lubi smak żywności typu fast-food. Najczęściej wskazywanym czynnikiem wpływającym na wybór żywności fast-food była cena. Najczęściej kupowanym produktem była pizza, a następnie zapiekanka. Większość badanych wyraziła opinię, że spożywanie żywności typu fast-food jest niekorzystne dla zdrowia.

Introduction

Eating out is not a common practice in Poland and in most of Polish families main meal is prepared at home. The research conducted in 2005 in central Poland demonstrated that only in 27.8% of investigated families at least one person had a meal out of home (JEŻEWSKA-ZYCHOWICZ and KOSICKA 2007). According to other research about 45% of Polish adults were food service users (KWIATKOWSKA 2007). In the United States 77% of meals eaten out were originated from fast food restaurants (GLAZER 2008). This type of food owes its popularity to the attractive flavour, quickness of preparation, reasonable prices and convenient locations of restaurants (BOWMAN and VINYARD 2004).

At the beginning, fast food producers were appreciated for creation tasty, inexpensive and simultaneously convenient food. Today, this type of products is perceived as unfavourable for health, deficient in nutrients and causing nutritional deficits in humans in a long term (STAUFFER 2003). According to the numerous authors (FRENCH 2003, LEDIKWE et al. 2005, JACOBS 2006) fast food eating can be the reason for nutritional irregularities, which can intensify and cause diet-related diseases such as obesity and type 2 diabetes, and also may have a detrimental effect on depression risk (SÁNCHEZ-VILLEGAS et al. 2012). It was found that consumers who reported eating fast food had higher intakes of energy, total fat, saturated fat, carbohydrate, protein and added sugars, and lower intakes of nutritious foods such as fruits and fluid milk than their counterparts who did not eat fast food (BOWMAN and VINYARD 2004). On the other hand, there is an opinion that fast foods may be a characteristic attribute of today's busy life and it is possible to find more healthy alternatives in this food sector (DAVIES and SMITH 2004). As the example the authors presented chicken salad sandwich. This product contains foods from three groups, namely: bread, other cereal and potato; meat, fish and alternatives; fruit and vegetables, and according to the label it makes an important contribution to protein and fibre intake. The authors suggested that if low fat spread and low fat mayonnaise were used and no salt was added this product

could be further improved. Recently, several fast food providers have reconsidered the recipes of their products and size of portions, and offered tools to control nutrients intake (SCHRÖDER and MCEACHERN 2005).

The group of people who are especially prone to the use of fast food are students as they usually live out of their place of permanent residence and therefore have to organize their meals themselves. Fast food restaurants are often conveniently located on or near campuses (KNUTSON 2000).

The objective of the present study was to analyze the impact of socio-demographic features such as gender, place of origin, financial situation of the family, self-perceived health status and physical activity on the fast food eating among the university students.

Methods

Participants

The research was conducted in 2009 on a group of 400 students at the University of Warmia and Mazury in Olsztyn, Poland. Potential participants in the study were approached at students' canteen and other university buildings and informed about the aim of the study. Those willing to take part in the research were handed the questionnaire for self completing. The questionnaires were collected directly after completing. The research group consisted of 69% women and 31% men. They originated from villages (44.8%), small towns below 25,000 inhabitants (21.1%), big towns of 25,000–100,000 inhabitants (25.0%) and cities of more than 100,000 inhabitants (9.1%). About half of them reported a good financial situation of their family (51.0%), whereas 42.5% declared fairly good, 4.4% very good and 2.1% bad financial situation. Participants were also asked to assess their health status – 56.5% marked good health status, 24.0% – fairly good, 18.8% – very good and 0.7% – bad health status. Most of them (62.5%) declared sporadic physical activity, 18.5% reported exercising 2-3 times a week, 15.6% pointed no physical activity and 3.4% declared everyday intensive physical activity.

Questionnaire

As a research tool a questionnaire was developed on the basis of literature review and discussions with students on their eating habits. The questionnaire consisted of the items concerning frequency of fast food eating (everyday/almost everyday, 3–5 times a week, 1–2 times a week, 1–2 times a month,

less than once a month, never), main reason for its eating (lack of time for preparing meal, influence of media, good taste, low price, don't like cooking, don't like canteen food, don't like canteen atmosphere, other), main factor influencing the choice of particular food (size of portion, price, quality of food, speed of service, nutritive value of food, other), fast food eaten most often (french fries, toasted baguette with vegetables/meat/cheese, french fries + hamburger, french fries + chicken, pizza, hamburger in bun, chicken, salad, other), and students' opinion on the fast food impact on health (favourable, neutral, unfavourable, no opinion). Respondents were asked to mark only one answer for each question.

Data analysis

The quantitative data collected in the survey were analysed using STATISTICA v.9. software package (StatSoft Inc., USA) in order to generate the relevant tabulations and conduct statistical tests. The analyses of data consisted of frequency distributions evaluation with chi-square statistics and p-values below 0.05 were considered significant.

Results and Discussion

Frequency of fast food eating

The research showed that about 22% of participants ate fast food at least once a week, and in further analysis they will be called frequent consumers (Table 1). The next 73% of students consumed this type of food no more than 1–2 times a month and can be described as occasional fast food eaters while almost 5% did not eat fast food at all.

The frequency of fast food eating was significantly affected by gender ($p<0.001$). More men than women were frequent fast food eaters (36.3% men vs. 16.0% women), while opposite relationship was observed among occasional consumers. The percentages of non-eaters were similar for men and women. Place of permanent residence did not affect significantly the frequency of fast food consumption by students. Nevertheless, respondents originated from villages and small towns were less frequent fast food users as 19.2 and 21.0% of them, respectively, reported eating at least once a week in comparison with 31.3% and 25.7% of frequent users in groups originated from big towns and cities, respectively. Although statistical analysis did not reveal a significant relationship between financial situation of respondents, their health status

Table 1

Frequency of fast food eating

Feature	Respondents [%] frequency of fast food eating						*p*-value
	everyday/almost everyday	3–5 times a week	1–2 times a week	1–2 times a month	Less than once a month	never	
Total sample	1.0	3.5	17.7	36.8	36.2	4.8	0.000
Gender							
men	2.5	4.8	29.0	37.1	21.8	4.8	
women	0.4	2.9	12.7	36.6	42.7	4.7	
Place of permanent residence							0.537
village	0.6	2.3	16.3	38.9	41.3	0.6	
town <25,000	0.0	4.9	16.1	37.1	40.7	1.2	
town 25,000–100,000	3.1	4.2	24.0	39.6	28.1	1.0	
city >100,000	0.0	5.7	20.0	34.3	40.0	0.0	
Financial situation							0.153
very good	5.9	0.0	47.1	23.5	23.5	0.0	
good	0.0	2.6	18.9	40.3	37.2	1.0	
fairly good	1.8	5.5	15.4	37.4	39.3	0.6	
bad	0.0	0.0	12.5	37.5	50.0	0.0	
Health status							0.059
very good	4.2	2.8	25.0	34.7	33.3	0.0	
good	0.0	2.3	17.5	39.2	39.6	1.4	
fairly good	1.1	6.5	16.3	40.2	35.9	0.0	
bad	0.0	33.3	0.0	0.0	66.7	0.0	
Physical activity							0.389
everyday intensive	0.0	7.7	7.7	53.8	30.8	0.0	
2–3 times a week	1.4	4.2	15.5	36.6	40.9	1.4	
sporadic	0.0	3.3	20.9	38.3	36.7	0.8	
no activity	5.0	3.3	15.0	36.7	40.0	0.0	

and physical activity, and frequency of fast food consumption, generally the better economic situation of participants was, the higher percentage of them reported frequent use of such food and the highest percentages of frequent fast food consumers were found in those groups of respondents who reported very good or bad health status. When physical activity of students is taken into consideration it could be suggested that those who practice intensive physical activity everyday pay more attention to healthy eating as 15.4% of them ate fast food 1–2 or 3–5 times a week (there were no everyday eaters among them) in comparison with 21.1–24.2% of frequent users in other groups.

The present study has shown that investigated students consumed fast food less frequently than their counterparts in other countries. The research conducted at the Michigan State University, USA, showed that among fast food eaters 40.4% ate at fast food restaurant three to four times a week. One third of the sample went there less frequently, while 25.8% ate there at least five times a week (KNUTSON 2000). Among Turkish students 60% ate fast foods at least once a week, with 8.4% consuming such food everyday (YARDIMCI et al. 2012). The vast majority of investigated Cyprus students (85.7%) have a dining experience once every two weeks (ZOPIATIS and PRIBIC 2007). Other studies carried out in Poland demonstrated that among the secondary school youth most of them consumed fast food once or twice a week (KOŚMIDER and GRONOWSKA-SENGER 2005). In the group of candidates to the Air Force College, 68.6% of respondents reported consumption of fast food, with about 30% of them eating such food at least once a week (GAŹDZIŃSKA et al. 2007).

Main reason for fast food eating

In the present study almost third of total sample answered that they use this type of food because they don't have time to prepare meals themselves (Table 2). The large group (24.3%) admitted that they like the taste of fast food and for 18.3% the main reason for fast food eating was its relatively low price.

The main reason for fast food consumption was not significantly affected by any of the socio-demographic features of students' however some differences can be reported. Higher percentages of women than men indicated "lack of time", "influence of media" and "it's tasty", whereas other reasons were more often selected by men. Almost a third of respondents originated from the cities marked "it's tasty" as a main reason for selecting fast foods as their meals, while among students living for permanent in other places it was "lack of time". When the financial situation was considered it was found that the better it was the higher percentage of participants reported "lack of time" and the lower percentage "it's tasty" as the most important reason for using fast food.

Table 2

Main reason for fast food eating

Feature	Respondents [%]								p-value
	reason for fast food eating								
	lack of time	influence of the media	taste	low price	don't like cooking	don't like canteen food	don't like canteen atmosphere	other	
Total sample	27.2	7.8	4.3	8.3	10.9	4.1	3.3	4.1	
Gender									0.398
men	24.7	4.6	21.8	20.1	13.8	6.9	3.5	4.6	
women	28.3	9.0	25.2	17.6	9.7	3.0	3.2	4.0	
Place of permanent residence									
village	30.0	7.1	24.5	15.7	11.3	2.5	2.3	6.6	
town <25,000	32.5	7.1	23.0	16.0	7.1	3.6	1.2	9.5	0.267
town 25,000–100,000	31.6	9.6	22.9	14.7	7.8	6.0	3.2	4.1	
city >100,000	26.9	6.4	29.5	11.5	10.3	2.6	2.6	10.3	
Financial situation									
very good	35.0	5.0	20.0	12.5	5.0	10.0	5.0	7.5	
good	32.0	7.9	24.4	14.6	9.0	2.8	2.1	7.2	0.241
fairly good	28.7	8.0	24.5	16.2	10.9	3.7	2.4	5.6	
bad	28.6	0.0	28.6	7.1	0.0	7.1	0.0	28.6	
Health status									
very good	31.5	6.9	23.9	13.2	10.0	6.3	5.7	2.5	
good	30.4	7.3	25.6	15.6	8.1	6.9	3.5	2.6	0.582
fairly good	30.7	8.9	21.3	15.3	12.4	7.4	2.5	1.5	
bad	28.6	14.3	28.6	14.3	14.3	0.0	0.0	0.0	
Physical activity									
everyday intensive	29.2	4.2	25.0	8.3	12.5	4.2	0.0	16.6	
2–3 times a week	31.1	5.4	25.8	16.2	10.2	2.4	2.4	6.5	0.551
sporadic	31.6	8.4	23.6	15.2	8.2	3.4	2.5	7.1	
no activity	27.1	8.3	25.0	14.6	13.2	5.6	2.1	4.1	

Only slightly less respondents who indicated no physical activity compared to more sporty respondents pointed out "lack of time" as their main reason for fast food eating.

It is slightly disturbing that quite considerable percentages of participants did not like eating in students canteen (did not like canteen food or canteen atmosphere), however it is conveniently situated in the central part of campus and offers a choice of full meals at reasonable prices. One can speculate that if the improvement in food quality and eating environment could take place to better suit the young people tastes there would be a chance to attract those students who eat fast food from the necessity and not because they really like it.

The results of the present study are in line with findings of other surveys. The research on the influence of age and gender on food choice revealed that women aged 18–30 were of the opinion that it was easier to prepare meals from ready-to-eat products and that fresh food was expensive (CHAMBERS et al. 2008). Women aged 31–59 found the temptation of unhealthy foods difficult to resist and lack of time made eating healthily more difficult. Women over 60 admitted that they thought unhealthy food tasted good and was, therefore, hard to resist. Men aged 18–30 found that lack of time and the convenience of unhealthy foods determined their eating habits. Lack of time was also crucial to men aged 31–59. Men over 60 said that they found it easy to eat healthily because of self-control and common sense.

Main determinant of fast food choice

None of the students features significantly affected determinants of fast food choice (Table 3). Regardless of a respondents' gender, price of food was the most often indicated factor. For men, the next important determinant of choice was size of portion, while for women, that was quality of food. Less than 5% participants were interested in nutritive value of fast foods.

In the groups of students who originated from villages, small towns and cities, the highest percentages indicated that quality of food plays a decisive role in their fast food choice, while among big towns inhabitants price of fast food was the most important factor. Price was also indicated by the highest percentage of respondents who evaluated their financial situation as fairly good. In other economic groups quality of food was marked most often. The worse health status was reported by respondents the more of them stated that size of portion influences their choice of fast food most. Among students characterized by a very good health status quality of food was the most important determinant of choice. Quality of food and speed of service were

Table 3

Main determinant of fast food choice

Feature	Respondents [%]						*p*-value
	determinant of fast food choice						
	size of portion	price	quality of food	speed of service	nutritive value of food	other	
Total sample	22.9	28.5	25.5	18.9	4.1	0.1	
Gender							0.472
men	25.0	29.6	22.5	19.2	3.3	0.4	
women	21.9	27.9	26.9	18.8	4.5	0.0	
Place of permanent residence							
village	20.4	23.9	26.5	24.2	4.1	0.5	
town <25,000	22.1	26.7	28.7	19.0	3.0	0.5	0.676
town 25,000100,000	20.8	30.4	25.8	19.2	3.8	0.0	
city >100,000	24.1	21.7	27.7	24.1	2.4	0.0	
Financial situation							
very good	18.6	23.3	32.6	20.9	4.6	0.0	
good	21.5	23.9	25.4	23.9	4.9	0.4	0.266
fairly good	21.1	28.7	27.9	19.4	2.7	0.2	
bad	20.0	25.0	30.0	25.0	0.0	0.0	
Health status							
very good	20.7	25.4	27.7	22.1	3.7	0.4	
good	21.0	22.2	25.6	25.6	5.0	0.6	0.325
fairly good	21.7	30.1	26.1	19.0	3.1	0.0	
bad	42.8	28.6	28.6	0.0	0.0	0.0	
Physical activity							
everyday intensive	24.0	16.0	24.0	28.0	8.0	0.0	
2–3 times a week	20.6	24.5	27.2	23.3	4.4	0.0	0.544
sporadic	21.5	26.5	26.5	21.5	3.5	0.5	
no activity	20.0	27.3	28.7	20.7	3.3	0.0	

equally important for participants declaring good health status, while in the group of fairly good health status it was price of food. Those participants who were involved in everyday intensive physical activity paid more attention to speed of service than students in other groups, where quality of food played the most important role in food choice.

The investigation of the attitudes of Swedish high-school students toward fast food eating showed that respondents were aware of the good and bad attributes of fast food, such as speed, convenience, fat and sugar. Female students viewed fast food in a broad food chain context, whereas male students concentrated on fast eating and satiety (MATTSSON and HELMERSSON 2007). In the case of undergraduate students from English and Scottish universities the motivations for purchasing fast foods were predominantly speed and convenience, flavour, value for money, and quality of ingredients (SCHRÖDER and MCEACHERN 2005). Importance of price, speed of service, consistency, convenient location and health concerns as main determinants for fast food choices were also reported by other researchers (KNUTSON 2000, BETTS et al. 1995). Additionally, it was determined that women were influenced more by factors such as speed of service, quality of menu items, feeling of safety and security and employees' professionalism compared to men (ZOPIATIS and PRIBIC 2007).

Most often chosen fast food

The type of food chosen most often by the respondents was significantly affected ($p<0.01$) only by gender of students (Table 4). Generally, the most often purchased fast food was pizza (29.8%) closely followed by toasted baguette with vegetables/meat/cheese. One can presume that when the meal was consumed in the restaurant or it was home-delivered, pizza was selected most often, but when the respondent was in hurry he/she chose toasted baguette and ate it in the street without stopping for the proper meal. More men than women preferred toasted baguette, hamburger in bun and chicken, while women more often than men purchased french fries, french fries + hamburger, french fries + chicken, pizza, and salad. It is also worth noting that a low percentage (2.6%) of participants selected french fries + chicken which could be treated as a full meal, especially when some salad or fruit was added. About 2% of respondents chose the healthy option of fast food, namely salads.

Permanent residents of villages and cities most often selected toasted baguette, whereas in groups of small and big towns residents pizza was the most popular fast food. When the financial situation of students is considered, it is observed that in the group of fairly good situation the highest percentage

Table 4

Most often chosen fast food

Feature	Respondents [%]									*p*-value
	fast food									
	french fries	toasted baguette with vegs/meat/ /cheese	french fries + hamburger	french fries + chicken	pizza	hamburger (in bun)	chicken	salad	other	
Total sample	10.0	29.1	4.7	2.6	29.8	12.9	0.3	2.1	8.7	
Gender										0.004
men	5.1	40.7	3.4	1.7	24.6	17.0	0.8	0.8	5.9	
women	12.2	24.0	5.3	3.0	31.9	11.0	0.0	2.7	9.9	
Place of permanent residence										
village	8.8	35.0	4.1	1.2	28.1	12.3	0.5	1.8	8.2	
town <25,000	10.0	21.2	2.5	6.3	31.2	13.8	0.0	3.8	11.2	0.624
town 25,000–100,000	13.7	25.3	6.3	1.1	32.5	12.6	0.0	1.1	7.4	
city >100,000	5.7	28.6	8.6	5.7	25.7	14.3	0.0	2.9	8.6	
Financial situation										
very good	0.0	17.6	23.5	5.9	35.3	5.9	0.0	0.0	11.8	
good	9.3	26.3	5.2	3.1	33.0	13.9	0.0	2.6	6.6	0.156
fairly good	11.7	34.6	2.5	1.9	24.1	12.3	0.6	1.9	10.4	
bad	12.5	12.5	0.0	0.0	50.0	12.5	0.0	0.0	12.5	
Health status										
very good	2.8	26.4	9.7	1.4	33.3	18.1	0.0	2.8	5.5	
good	10.7	29.9	3.3	2.3	32.3	10.7	0.0	1.9	9.0	0.165
fairly good	13.0	30.4	3.3	4.3	20.7	14.1	1.1	2.2	10.9	
bad	33.3	0.0	33.3	0.0	33.3	0.0	0.0	0.0	0.0	
Physical activity										
everyday intensive	7.7	30.8	0.0	0.0	46.1	0.0	0.0	7.7	7.7	
2–3 times a week	7.2	31.4	4.3	4.3	34.3	11.4	1.4	1.4	4.3	0.809
sporadic	10.9	29.4	5.5	2.1	26.9	13.5	0.0	2.1	9.6	
no activity	10.0	25.0	3.3	3.3	31.7	15.0	0.0	1.7	10.0	

of respondents indicated toasted baguette as the most often selected fast food, while in other economic groups it was pizza. Pizza was also the most popular fast food among those participants who evaluated their health status as very good and good. Among students who reported bad health status the indications were evenly distributed between french fries, french fries + hamburger and pizza. The analysis of physical activity effect on the most often chosen fast food showed that the higher percentage of respondents involved in everyday intensive physical activity selected salads (7.7%) than in other groups (1.4–2.1) and none of the students in this group indicated purchasing hamburgers or chicken alone or in combination with french fries. These results seem to confirm earlier observations that this group of consumers is more health conscious than other groups.

Other studies show that women were more likely to consume foods in line with dietary guidelines (BOGUE et al. 2005). They also observed that respondents over 35 were the most concerned about their health, and additionally respondents aged 35–54 were more knowledgeable about dietary issues than younger and older respondents. It was also reported that younger respondents were less likely to report that "trying to eat a healthy diet" was imported to them (KEARNEY et al. 2000).

Opinion on the fast food influence on health

The vast majority of respondents (87.4% of total sample) expressed an opinion that fast food is unfavourable for health (Table 5). More men than women were of opinion about neutral effect of this type of food on health. The highest percentage of "unfavourable influence" opinions was found among big town inhabitants, however in this group the only "favourable influence" opinions were also observed. The percentage of "unfavourable influence" opinions increased gradually from 80.6% in the group of very good health status to 100% in the group of bad health status. Nevertheless, the statistical analysis demonstrated that only physical activity of participants affected significantly ($p<0.05$) their opinions on the fast food influence on health. More respondents expressed a "neutral influence" opinion in the group of everyday physical activity students than in other groups and additionally the lowest percentage of "unfavourable influence" opinions was observed in this group. All respondents who indicated the "favourable influence" opinion simultaneously reported no physical activity.

The awareness of food "healthiness" was observed by KNUTSON (2000) who found that about 60% of college students indicated the same fast food restaurant as a source of highest nutrition quality and best for vegetarians foods.

Table 5

Students' opinion on the fast food influence on health

Feature	Respondents [%]				p-value
	fast food influence on health				
	favourable	neutral	unfavourable	no opinion	
Total sample	0.3	10.2	87.4	2.1	
Gender					0.084
men	0.0	15.3	81.4	3.3	
women	0.4	8.0	90.1	1.5	
Place of permanent residence					
village	0.0	12.3	86.5	1.2	
town <25,000	0.0	10.0	85.0	5.0	0.349
town 25,000–100,000	1.1	6.3	90.5	2.1	
city >100,000	0.0	11.4	88.6	0.0	
Financial situation					
very good	0.0	17.6	70.6	11.8	
good	0.0	10.3	88.7	1.0	0.067
fairly good	0.6	9.3	88.3	1.9	
bad	0.0	12.5	75.0	12.5	
Health status					
very good	1.4	13.9	80.6	4.2	
good	0.0	10.3	87.9	1.9	0.456
fairly good	0.0	7.6	91.3	1.1	
bad	0.0	0.0	100.0	0.0	
Physical activity					
everyday intensive	0.0	23.1	69.2	7.7	
2–3 times a week	0.0	15.7	80.0	4.3	0.029
sporadic	0.0	6.7	92.4	0.8	
no opinion	1.7	15.0	80.0	3.3	

Conclusions

The results of the study show that fast foods eating among the investigated students' group is generally kept at the moderate and reasonable level as a vast majority of them eat it only occasionally. Respondents' gender had a significant impact on the frequency of fast food eating and most often chosen fast food, while physical activity significantly affected students' opinion on the fast food influence on health. Financial situation and health status did not show significant effect on any of the analyzed phenomena.

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CONTENT OF *CIS9TRANS*11 C18:2 ACID (CLA) AND *TRANS* ISOMERS OF C18:1 AND C18:2 ACIDS IN BUTTERS

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K e y w o r d s: butter, fatty acids, *trans* isomers, CLA.

A b s t r a c t

The aim of this study was to evaluate the fatty acid composition, including the content of conjugated linoleic acid *cis*9*trans*11 C18:2 (CLA) and *trans* isomers C18:1 and C18:2 acids, in 17 butters come from different producers available on the Olsztyn market. Determinations were carried out with the GC method using a 100 m capillary column with CP Sil 88 phase.

In all the analysed butters *cis*9*trans*11 C18:1 acid and *trans* isomers of C18:1 and C18:2 acids were found. The percent content of CLA in total fatty acids in fat butters was ranged from 0.53 to 1.13%, *trans* C18:1 ranged from 2.12 to 3.72% and *trans* C18:2 from 0.62 to 1.17%. A short-chain fatty acids in fat examined butters were ranged from 4.93 to 10.40%, saturated fatty acids from 52.82 to 60.08%, monounsaturated from 26.84 to 36.62% and polyunsaturated from 2.74 to 6.29% of total fatty acids.

ZAWARTOŚĆ KWASU *CIS9TRANS*11 C18:2 (CLA) I IZOMERÓW *TRANS* KWASU C18:1 I C18:2 W MASŁACH

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S ł o w a k l u c z o w e: masło, kwasy tłuszczowe, izomery *trans,* CLA.

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Abstrakt

Przedmiotem badań była ocena składu kwasów tłuszczowych, ze szczególnym uwzględnieniem zawartości kwasu linolowego o wiązaniach sprzężonych *cis*9*trans*11 C18:2 (CLA) oraz izomerów *trans* kwasu C18:1 i C18:2 w 17 masłach dostępnych na rynku w Olsztynie. Oznaczenia przeprowadzono metodą GC na 100-metrowej kolumnie kapilarnej z fazą CP Sil 88.

We wszystkich badanych produktach stwierdzono obecność kwasu *cis*9*trans*11 C18:2 (CLA) oraz izomerów *trans* kwasu C18:1 i kwasu C18:2. Udział CLA w ogólnym składzie kwasów tłuszczowych tłuszczu badanych maseł wynosił od 0,53 do 1,13%, izomerów *trans* kwasu C18:1 od 2,12 do 3,72%, a kwasu C18:2 od 0,62 do 1,17%. W tłuszczu wydzielonym z badanych maseł udział kwasów krótkołańcuchowych w ogólnym składzie kwasów tłuszczowych wynosił od 4,93 do 10,40%, kwasów nasyconych od 52,82 do 60,08%, monoenowych od 26,84 do 36,62%, a polienowych od 2,74 do 6,29%.

Introduction

Butter is a high-fat product manufactured exclusively from cow's milk as a result of the so-called churning of specially-prepared sour or sweet cream. The quality of milk fat is determined, primarily, by the composition of its fatty acids, the properties of which depend on the length of the carbon chain and the presence of unsaturated bonds. Unlike other natural fats, the milk fat is a complex fat, for it contains over 400 different fatty acids, many of which exert beneficial effects on human health. The quantitative composition of fatty acids of cow;s milk is changing under the influence of multiple factors, including: the feeding system of animals, breed of cows, lactation period, individual characteristics and health status of cows, and others. Out of these factors, the most significant effect is ascribed to the feeding system (JAWORSKI 1978, 1995). Milk fat from the summer period is characterised by significantly higher contents of C18 group fatty acids, including mainly fats from the C18:1 group, and by significantly lower contents of palmitic and myristic acids than the milk from the winter period (JAWORSKI 1978, JENSEN 2002, ŻEGARSKA 1988). A unique characteristics of milk fat, contributing to its high digestibility, is the presence of short- and medium-chain fatty acids. Butyric acid, whose concentration in milk fat reaches 3–4% of total fatty acids, has been found effective in the treatment of nipple and colon cancer (CICHOSZ 2009, ŻEGARSKA 2005). In turn, vaccenic acid (*trans* 11) constituting over 50% of all *trans* isomers of C18:1 acid in milk fat, has been shown to exhibit anticarcinogenic and antiatherosclerotic actions (PRZYGOJEWSKA and RAFALSKI 2003). Milk fat constitutes the main, dietary source of conjugated linoleic acid (CLA) characterised by a variety of health-promoting properties, including: anticarcinogenic, antidiabetic, anti-inflammatory and antiatherosclerotic effects (BIAŁEK and TOKARZ 2009, PARIZA 1991, PARODI 1999). It is also a source of other components implicated to exert beneficial effects on human health, e.g. phospholipids, fat-soluble vitamins and β-carotene.

Owing to a high intake of butter by Polish consumers and to a rich assortment of butter products available on the Polish market, the assessment of their quality is of great importance. In view of this, the objective of this study was to determine the composition of fatty acids, with special emphasis put to concentrations of conjugated linoleic acid *cis*9*trans*11 C18:2, CLA) and *trans* isomers of C18:1 and C18:2 acids, in extra butters available on the market of the city of Olsztyn.

Material and Methods

Material

The study comprised 17 butter samples purchased in the retail shops in Olsztyn, in October and November. The butters, containing 82–83% fat come from different producers.

Analytical methods

Fat from the butters was separated by melting, decantation and filtering through anhydrous sodium sulfate.

Methyl esters of fatty acids were prepared according to the IDF method using a methanol solution of KOH (*IDF Standard 182*... 1999).

The total composition of fatty acids of the isolated fat was determined by gas chromatography (GC) using a Hewlett Packard 6890 chromatograph (Palo Alto, CA), with flame-ionization detector and capillary column CP Sil 88 (100 m, 0.25 mm I.D., 0.20 μm film thickness); the column temperature was 60°C (1 min) – 180°C, $\Delta t=5$°C/min; split ratio:1:100; the injector and detector temperature: 225°C and 250°C, respectively; carrier gas: helium, flow 0.8 mL /min.

Identification of methyl esters of the *trans* fatty acids and linoleic acid with conjugated bonds was carried out by comparing their retention times with those of standards (Sigma and Supelco) and literature date (PRECHT and MOLKENTIN 1994, PRECHT and MOLKENTIN 1997b, PRECHT and MOLKENTIN 1999, RATNAYAKE et al. 1992, WOLFF and BAYARD 1995). The content of fatty acids was expressed as a percentage (weight %) of the total fatty acids. All measurements were performed in duplicate.

Results and Discussion

The content of particular groups of fatty acids in fat extracted from the butter samples examined was presented in Table 1. Results of the determination of *cis*9*trans*11 C18:2 acid (CLA) and the total content of *trans* isomers of C18:1 and C18:2 acids were presented in Figure 1. The exemplary chromatogram separation of *trans* isomers C18:1 and C18:2 acids of butter is presented in Figure 2.

Table 1

Percentage of some groups of fatty acids (% of total fatty acids) in fat of analysed butters

Product	Σ short-chain fatty acids	Σ saturated fatty acids	Σ monounsaturated fatty acids	Σ polyunsaturated fatty acids	Σ *trans* fatty acids
1	5.42	55.10	33.20	6.29	3.41
2	9.68	58.18	28.68	3.46	5.76
3	7.17	56.54	31.66	4.63	5.43
4	10.09	58.64	27.93	3.34	5.58
5	4.93	52.82	36.62	5.65	6.72
6	9.38	58.86	28.48	3.28	5.03
7	9.17	59.12	28.59	3.12	4.77
8	10.18	58.88	27.68	3.26	5.20
9	9.87	58.58	28.30	3.25	4.41
10	10.33	58.55	27.75	3.37	4.99
11	8.53	57.64	29.57	4.26	3.40
12	10.38	58.86	27.68	3.08	4.78
13	9.58	59.30	27.74	3.38	4.66
14	9.88	59.15	27.33	3.64	5.63
15	10.35	58.12	28.15	3.38	5.66
16	10.40	59.64	26.84	3.12	4.56
17	9.84	60.08	27.34	2.74	4.02
Mean ± SD	9.13 ± 1.69	58.12 ± 1.80	29.03 ± 2.54	3.72 ± 0.96	4.82 ± 0.72

In fat extracted from the butter samples the short-chain fatty acids (C4:0 – C10:0) ranged from 4.93 to 10.40% of the total fatty acids composition (Table 1). In all butter samples examined, the highest content in that group of fatty acid was noted for butyric acid (C4:0), *i.e.* from 1.58 to 3.38%.

From the nutritional viewpoint, the unbeneficial characteristics of milk fat is a high content of saturated fatty acids that constitute ca. 56% of the total fatty acids of milks fat (JAWORSKI 1978, STANIEWSKI 2000). The total content of saturated fatty acids in fat extracted from butter samples ranged from 52.82%

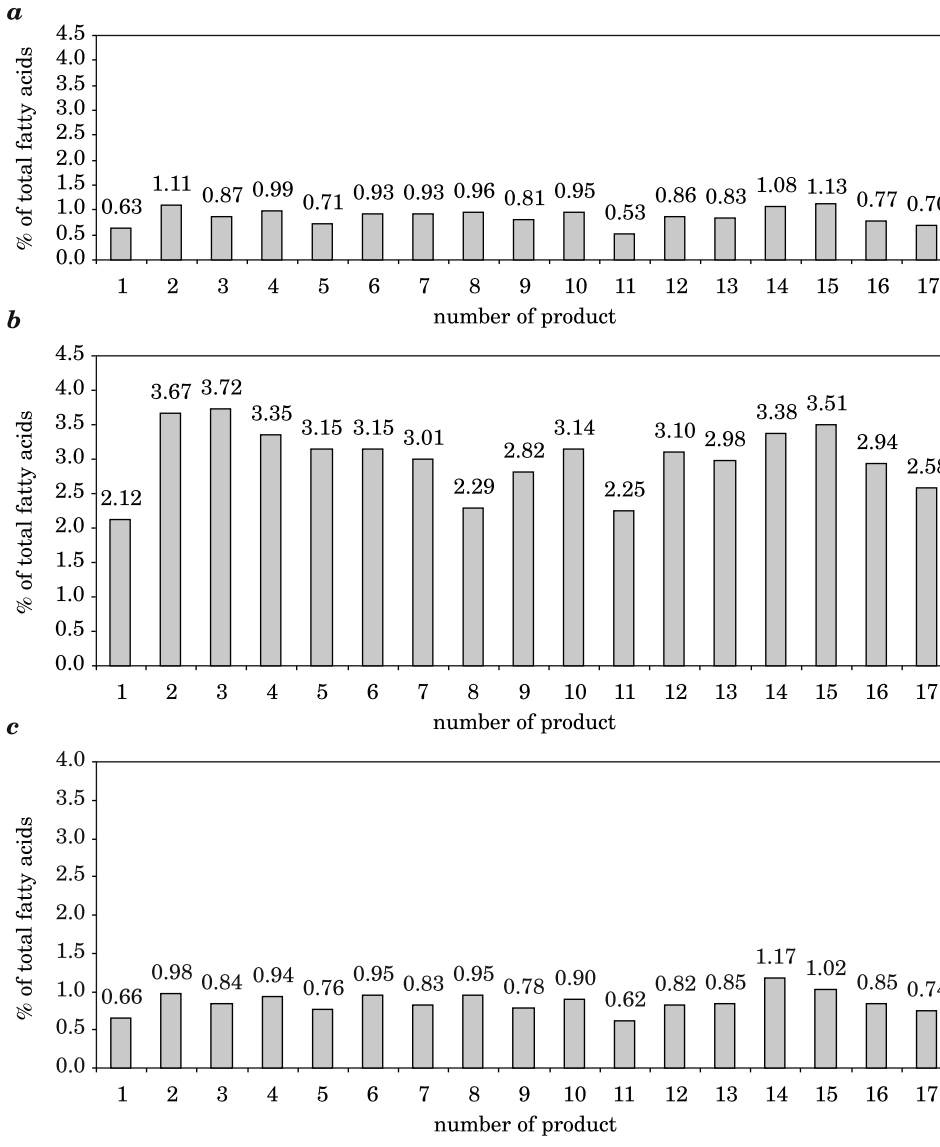

Fig. 1. The content of: *a* – cis9*trans*11 CLA, *b* – *trans* C18:1, *c* – *trans* C18:2 in the total fatty acids composition of fat isolated from the analysed butters

to 60.08% (Table 1). Those acids were mainly represented by palmitic acid (C16:0) which constituted from 27.84 to 36.46%, and by stearic acid (C18:O) which constituted from 7.25 to 10.50% of the total fatty acids composition.

In milk fat, the monoenoic acids constitute *ca.* 30% of the total fatty acids (JAWORSKI 1978, STANIEWSKI 2000). In the analysed butter samples, the total

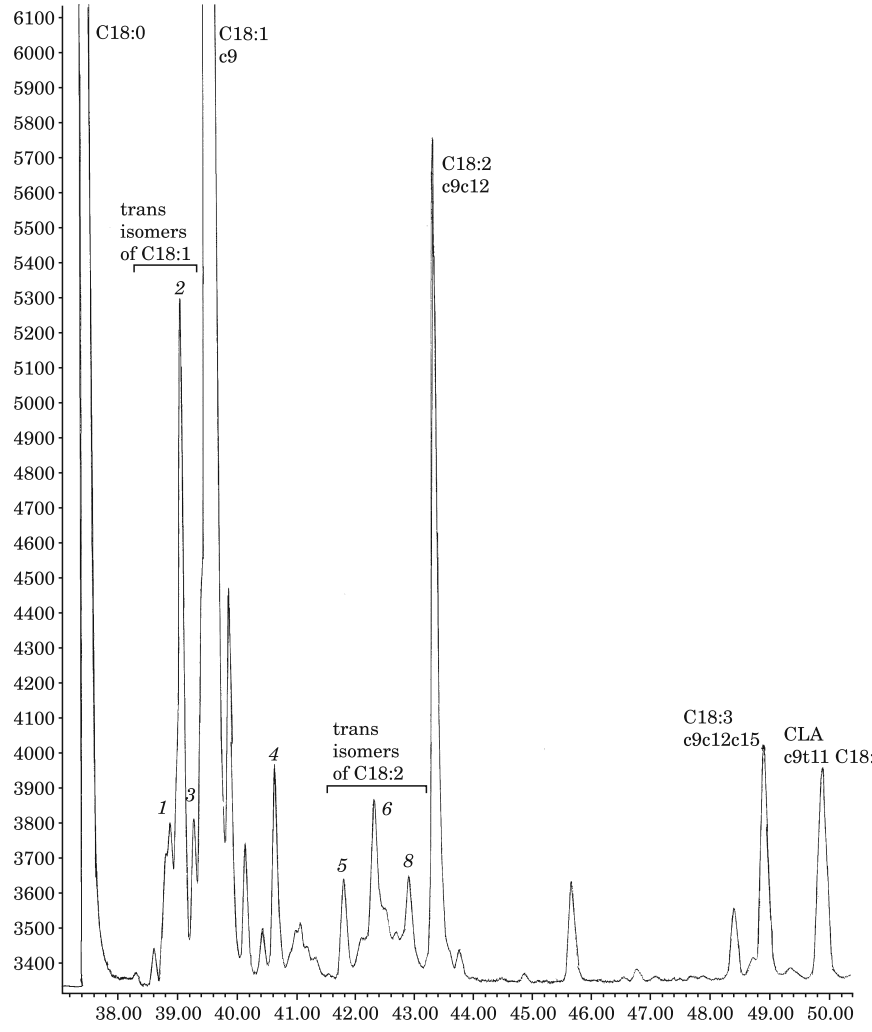

Fig. 2. Separation of *trans* isomers of C18:1 and C18:2 fatty acids of butter by GC. Identyfication: *trans* isomers of C18:1 (*1 – trans* 6–9; *2 – trans* 10+11; *3 – trans* 12; *4 – trans* 16); *trans* isomers of C18:2 (*5 – cis*9*trans*13; *6 – cis*9*trans*12; *7 – trans*9*cis*12; *8 – trans*11*cis*15)

content of those acids ranged from 26.84 to 36.62% of the total fatty acids composition. They were the most frequently represented by oleic acid (*cis* 9 C18:1), whose content reached 18.72 to 23.35% of the total fatty acids composition. Worthy of notice are antiatherosclerotic properties of this acid (ZIEMLAŃSKI and BUDZYŃSKA-TOPOLOWSKA 1991).

Milk fat is a poor source of polyenoic fatty acids (JAWORSKI 1978, STANIEWSKI 2000, ŻEGARSKA 1988). In fat extracted from the butter samples

examined the content of those acids ranged from 2.74 to 6.29% of the total fatty acids composition (Table 1). In all butter samples the predominating turned out to be linoleic acid (*cis*9*cis*12 C18:2) which constituted from 1.20 to 4.90%, linolenic acid (*cis*9*cis*12*cis*15 C18:3) which constituted from 0.39 to 0.76% of the total fatty acids composition.

Fat extracted from all butter samples contained conjugated linoleic acid (*cis*9*trans*11 C18:2, CLA), *trans* isomers of C18:1 acid as well as *cis,trans* / *trans,cis* isomers of C18:2 acid.

The linoleic acid with conjugated bonds (*cis*9*trans*11 C18:2) is a predominating constituent of conjugated dienes of milk fat, and is implicated to exert anticarcinogenic, antiatherosclerotic, immunomodulating and antioxidative effects. In fat extracted from the studied butter samples its content ranged from 0.53 to 1.13% (Figure 1). The content of CLA in milk varied in a wide range depending on the period of cows feeding. Higher contents of this acid are reported in milk fat originating from the period of pasture feeding, whereas lower ones from the period of stall feeding (PRECHT and MOLKENTIN 1997a, ŻEGARSKA et al. 1996). Results achieved in this study indicate that the butters examined were produced from milk originating from pasture or intermediate (October, November) feeding period (ŻEGARSKA et al. 2006). According to a study by BARTNIKOWSKA et al. (1999), in samples of butter produced in the winter (December, January and February) the mean content of CLA reached 0.45%, whereas in those produced from milk originating from the summer period (June, July, August) it constituted 1.2% of the fatty acids pool. A research by ŻEGARSKA et al. (2005) indicates that in samples of butters purchased in the summer the content of CLA ranged from 0.8 to 1.6% of the total fatty acids composition.

The total content of *trans* isomers of C18:1 acid in the butter samples examined fluctuated between 2.12 and 3.72% of the total fatty acids composition (Figure 1). In fat of all analysed butter samples, in the group of *trans* isomers of C18:1 acid the highest contents were reported for *trans*10 + *trans*11 isomers. Their contents were summarised due to their incomplete separation in some butter samples. Following literature data, the major *trans* isomer of C18:1 acid in milk fat is vaccenic acid (*trans*11), which constitutes over 50% of the total *trans* isomers of C18:1 acid, on average (PARODI 1976, ŻEGARSKA et al. 1996). This acid exhibits antiatherosclerotic properties and exerts a positive effect by inhibiting the growth of cancer cells of colon and other organs. Vaccenic acid is a substrate to the endogenous synthesis of CLA (BARTNIKOWSKA 2001, GRINARI et al. 2000, SANTORA et al. 2000). It has been estimated that *ca.* 64% of CLA in milk fat originated from the endogenous synthesis from *trans*11 acid mediated by delta-9 desaturase. According to literature data (PARODI 1976, PRECHT and MOLKENTIN 1997b, PRECHT and

MOLKENTIN 2000), the contribution of *trans*10 acid in milk fat reaches as little as *ca.* 5.5%. In butter samples analysed in this study, the total content of *trans*10 + *trans*11 isomers made up from 53% to over 70% of the total content of *trans* isomers of C18:1 acid.

According to a research by WOLF (1994), French butters from October-November contained 3.22% and those from May–June – 4.28% of *trans* isomers of C18:1 acid, on average. In turn ARO et al. (1998) report that the content of *trans* isomers of C18:1 acids in butters originating from different European countries ranged from 2.16 to 3.64%. BARTNIKOWSKA et al. (1999) demonstrated that in samples of butter produced in the winter (December, January, February) the mean content of *trans* isomers of C18:1 acid accounted for 1.4%, whereas in those of butter produced in the summer (June, July, August) for 3.55 of the fatty acids pool. Higher contents of those isomers in samples of butter purchased in the summer were reported by ŻEGARSKA et al. (2005). The samples of butters analysed in this study contained from 4.6 to 5.8% of those isomers. A research by DANIEWSKI et al. (1998) indicates that the total content of *trans* isomers of C18:1 acid in butters reached 0.59% in "Masło śmietankowe" and 3.72% in "Masło ekstra".

In fat extracted from the analysed butter samples, the content of *cis,trans* and *trans,cis* isomers of C18:2 acid ranged from 0.62 to 1.17% (Figure 1). A similar content of *trans* isomers of C18:2 acid, reaching from 0.8 to 1.3%, was demonstrated in butters investigated by ŻEGARSKA et al. (2005). According to data from another study of those authors (ŻEGARSKA et al. 2006), the content of *trans* isomers of C18:2 acid in milk fat from the summer period ranged from 0.65 to 1.19%, in milk fat from the intermediate period – from 0.51 to 1.07%, and in milk fat from the winter period – from 0.29 to 0.61% of the total fatty acids composition.

Conclusions

Contents of conjugated linoleic acid (*cis*9*trans*11 C18:2) and *trans* isomers of C18:1 and C18:2 acids in fat extracted from the investigated butters available on the Olsztyn market approximated respective contents demonstrated in milk fat. This may indicate that the level of *trans* isomers in butter is affected, to a significant extent, by the quality of raw material used for its production.

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