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Evaluation of the environmental impact of different methods of carp production in Petrykivskiy fish farm

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Environmental impacts of different systems of pond carp culturing - extensive (mainly on natural food) and intensive. For each production system, main qualitative features of production cycle are regarding their impacts: physic-chemical and biological with regard to the production technology. The feeds, especially fish meal, were the main impact contributor and were considered in aspect using of fossil fuels and biotic resources for their production and application.

Key words: aquaculture; life cycle assessment; fishpond; aquafeed; food organisms

Оценивание разных систем кормления карпа и их влияние на окружающую среду в хозяйстве Петриковского рыбхоза

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Сравнено разные производственные системы получения товарной массы карпа в прудах при выращивании экстенсивным (преимущественно на натуральных кормах) и интенсивным способами. Для каждой производственной системы приведены основные показатели производства соотнесенные на единицу полученной товарной массы рыбы. Определено их влияние на окружающую среду физико-химические и биологические изменения. Рассматривается несколько технологий выращивания товарного карпа, как основного вида, в аспекте негативного воздействия процесса кормления рыбы, использования горюче-смазочных материалов и других ресурсов на окружающую среду.

Ключевые слова: аквакультура; оценка жизненных циклов; пруд; корма для рыб; пищевые организмы

Оцінка різних систем годівлі карпа та їх вплив на навколишнє середовище у господарстві Петриківського рибгоспу

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Порівняно різні виробничі системи отримання товарної маси коропа у ставках при вирощуванні екстенсивним (переважно на природних кормах) та інтенсивним способами. Для кожної виробничої системи наведені основні якісні показники виробництва співвіднесені на одиницю отриманної товарної маси риби. Визначений їх вплив на навколишнє середовище, а саме фізико-хімічні та біологічні зміни за різних технологій вирощування товарного коропа, як основного виду в аспекті негативного впливу годівлі риби. Серед основних ресурсів необхідних для

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виробництва товарної маси коропа слід виділити: сільськогосподарські землі, воду, сонячну енергію, основні біогенні елементи (азот, фосфор, оліго-елементи та мікроелементи), викопну енергію палив, біотичні ресурси, що використовуються, здебільшого, для виробництва сировини для комбікормів. Біологічний цикл рибного ставку потребує однак постійного притоку вуглецю у вигляді CO_2 та сонячної енергії, азоту (N) та фосфору (P). Потреба в енергії для ставкового рибного господарства в основному пов'язана з транспортуванням та обробкою кормових інгредієнтів. З огляду дослідження життєвого циклу виділено основні екологічні проблеми для основного елементу ланцюгу постачання рибних харчових продуктів, а саме навантаження, що створює виробництво на екосистеми внутрішніх водойм, які використовуються у рибогосподарських цілях. За усіма групами перехід на екстенсивну систему забезпечує певний рівень покращення загальних показників за результатами проведення узагальненого аналізу. Врахування навантаження, що створюється виробничим циклом на оточуюче середовище є невід'ємною складовою конкурентоспроможного на ринку господарства в галузі аквакультури. Стійкість технологічного циклу у певних конкретних умовах ведення аквакультури та розроблення заходів щодо їх запровадження є необхідними у сучасних умовах господарювання.

Ключові слова: аквакультура; оцінка життєвих циклів; ставок; корма для риб; харчові організми

Introduction

According to analytical data, the increase of annual fish protein supply to 16 Mt, or 7 Mt above 2006 levels is expected. This would meet 14 percent of the necessary increase in global animal protein supply estimated by FAO for 2050. Aquaculture, the cultivation of aquatic organisms for the human consumption, is one of the fastest growing animal production activities worldwide. The sustainable sourcing of aquafeeds for fish nutrition is considered one of the main priorities to reduce the environmental impact of this industry.

Drastic decrease in intensive full-cycle fish farming sector of Ukraine induced the switch to the homestead ponds and extensive fish culture, when fry and fingerlings collected from natural water bodies or hatcheries are seeded into ponds, large or small and harvested at the end of the year or end of second year. Full – cycle production technologies (from seed to market product) investigated during 50s – 70s are proved to be six-eight times more efficient in terms of production rate than one year extensive growing cycle but require significant capital investment, which is risky in the current economic situation.

Extensive "grow-out" techniques appeared to be more appropriate and existing practice indicated that, first, following measures are required:

1) Enhance the natural productivity of the pond through the correction of nutrients balance;
2) Adjustment of fish stocking, species compatibility and density, size and proportions;
3) Correction of supplementary feed scheme, its kind and quality of feedstuffs, which should be considered as supplementary food source for fish.

Extensive pond carp culture farming could be considered as more environmentally safe as well, as production of feed is the most energy intensive and environmentally damaging aspect of aquaculture (and all animal agriculture).

Replacement of conventionally animal-based feed with natural food (aquatic organisms) for fish can be more environmentally beneficial.

The aquatic environment supports various communities of living organisms. They constitute the biotic load of a pond. Plankton designates the community of pelagic organisms, composed of various groups, which are in suspension in water and hence restricted mobility, often less than that of the water, which carries (Salazkin & Ivanova, 1982).

Phytoplankton or photosynthetic organisms and zooplankton or heterotrophic organisms, found in ponds, consist of a large number of taxa. Zooplankton distribution within ponds is non-homogenous and related to food availability and avoidance of predators. Distribution varies with time, due in particular, to vertical

Diel movement from the warm, food-rich surface layers to cool provide vertical migration results in predator avoidance by zooplankton and fluctuations of the grazing pressure owing to vertical migration enables unimpeded growth of the algae during daytime (Shpet, 1953).

Increased predation pressure caused by higher fish density dramatically changed the structure of zooplankton assemblages in the ponds (Shcherbina, 1983). The large organisms like Daphnia spp. are substituted by small zooplankton species (Shpet, 1953) that are not able to efficiently regulate phytoplankton growth, especially the biomass of blooming cyanobacteria with long filaments (Ciric et al., 2013). The high cyanobacteria biomass, which cannot be effectively used by the higher trophic levels, results in instability of the pond ecosystem through decomposition of excessive organic matter, fluctuation of dissolved oxygen and water pH (Dandin et al., 2003). The use of supplemental fish feed with appropriate characteristics could decrease predation pressure on large zooplankton, and at the same time serve as a source of nutrients for production of carp natural food (zooplankton and benthic invertebrates). Energy and nutrients transformation can be generally described through the nutritional chain (fig. 1).

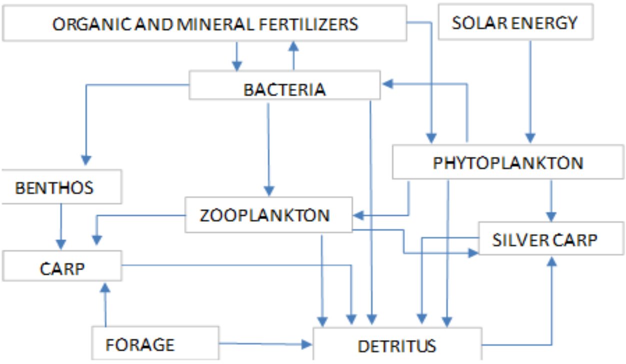

Fig. 1. Mineral organic matter and energy transformation in pond through the food chain

Mineral nitrogen can be directly assimilated by some groups of bacteria, nitrogen from organic fertilizer decomposition and when mineralized is directly used by phytoplankton organisms to build up cell mass. Bacteria can decompose dead cells and external metabolites of phytoplankton and inorganic forms of nitrogen enrich pond water back (Oglesby, 1977).

Living bacterial mass as well as phytoplankton mass becomes food for zooplankton. Part of dead bacterial cells fall down onto pond bottom and form detritus and can be consumed by benthos. Silver carp directly consume part of phytoplankton biomass, while main part of benthos becomes food for carp as well as major part of zooplankton mass.

Some part of dead zooplankton organisms fall down onto pond bottom and form detritus as well as fish feces fall down and form detritus as well as not consumed forage, all this organic mass becomes substrate for benthic organisms. Phosphorous undergo same ecological pathways thus it is possible to apply biogenic manipulation increase the ratio of nitrogen to phosphorus in the water of the eutrophicated reservoir (Alekin et al., 1973). The uniqueness of the method lies in the fact that the necessary increase is achieved not by reducing the amount of phosphorus, but by adding nitrogen compounds to the eutrophicated pond. As shown above model and experimental studies, under certain ratios of nitrogen to phosphorous, biogenic manipulation leads to suppression of the cyanobacteria blooming and dominance of green microalgae species (Luzhin, 1976).

Application of organic fertilizers for stimulation of natural pond productivity can serve dual purpose – provide low cost and qualitative product (fish) and significantly decrease eutrophication potential associated with standard pond fish culturing (Curran, 1993).

All listed above manipulations are proved effective when expetnsive fish culturing is performed but not enough literature data is available for evaluation of the environmental impact of such fish production cycle compared to the standard technology.

Life cycle assessment (LCA) is recognized as a standardized and structured method of evaluating the environmental impacts arising throughout the entire life cycle of a product, process or activity. However, methodological issues still exist, when allocating the environmental burden of a specific production system between products and co-products. This study is aimed to evaluate two market fish production patterns based on the data collected from fish farm implementing extensive technology instead of standard intensive recently (ISO 14044).

Materials and methods

Description of Study Facility. Petrikovsky fishfarm is situated in the Petrikovsky region of Dnipropetrovskaya oblast. “Petrikovsty fish farm” is the private agrarian enterprise under the law of Ukraine, which supply many regions Ukraine with fish products.

Such fish breeds as Ukrainian carp, grass carp, and silver carp are cultured in the farm. In 2011 farm reached overall productivity rate of 250 metric tons of fish.

According to the state fish agency data, fish farm ponds total area is 1367 ha and potential overall farm productivity is estimated at rate of 273 t of fish per year.

During last five years farm switched mainly to extensive farming of carp and silver carp due to unstable supply and price for raw forage feedstock.

General conditions for culturing and ponds’ productivity were studied and compared to data for previous years when high intensive carp culturing was in practice to evaluate general ecology-toxicological state of ponds and asses environmental impact of the fish production cycle.

Hydrobiological assessment. Physico-chemical parameters of the water were analyzed following standard methods (MBB 08.12-0109-03; KND 211.1.4.039-95; MBB 08.12-0651-09; MBB 08.12-0005-01; KND 211.1.4.023-95; KND 211.1.4.024-95; KND 211.1.4.021-95; MBB 08.12-0317-06; MBB 08.12-0653-09; MBB 08.12-0004-01; MBB 08.12-0109-03; MBB 08.12-0106-03). Parameters like temperature, pH and electrical conductance measured with HANNA HI98129 water express tester, dissolved oxygen concentration was measured with HACH HQ 30d analyzer, dissolved solids concentration – with Ezodo TDS 5032 tester, penetration of light with Secchi disc, fixation of samples was done on the spot. For the rest of the parameters, 500 ml lake water was collected and analyzed in the laboratory.

To evaluate planktonic biota, the samples were collected with the help of plankton net made up of blotting silk No. 25 (0.3 mm mesh) and fitted with a wide mouthed bottle. Bottom sampler was used for collection of benthos samples. The collected samples were preserved in 4% formaldehyde solution (Alekin et al., 1973).

Sampling and determination was performed according to “Methods of hydrobiological studies of surface waters” (Arsan et al., 2006).

LCA basis. According to International Standards Organization (ISO) 14000 series, the technical framework for LCA methodology, as it is defined in ISO 14040 consists of four phases: goal and scope definition; inventory analysis; impact assessment; and interpretation (ISO, 2006a).

In our analysis, we examine the contribution of the different production phases to the total environmental impacts and to compare two different market carp production systems in Ukraine.

Foreground data were collected directly from Utd. Pretrikovsky fish farm. Data are collected using detailed questionnaires filled onsite and with interview with production managers of the farm which recently switched from intensive carp farming to extensive technology.

To date, LCA studies methods are less “limited” than other methods of the environmental assessment, this it is more widely used by different environmental protection organizations (Agri-footprint). Despite the diversity of LCAs addressing the environmental characterization of intensive aquaculture practices, a common conclusion can be drawn: the leading role played by feed (ELCD database, 2012).

Operational material/energy inputs and production associated with farm operations during last 10 years were collected during regular visits. In this case, it should be noted that, although a few materials such as blood meal, hemoglobin and vitamins are not included in the ecoinvent database, data relating to their production were based on compounds actually included in this database and which were assumed as equivalent for the purposes of this study.

Evaluation of nutritional value of natural pond planktonic organisms was calculated on the principle of substituting, when nutritive fish ration components, raw fat and protein in natural fish ingredients were calculated as positive and aquafeed ingredients as negative. Nutritive value for produced aquafeed ingredients and planktonic organisms were based on data provided after studies Yi. Zheltov, I. Sherman and A. Chaplina (Zheltov et al., 2013).

Table 1

Nutritive value of aquafeed ingredients and zooplankton organisms for fish

Aquafeed ingredient	Ration in aquafeed composition, %	Dry matter %	Digestible protein, %	Digestible fat, %	FCR	References
Ingredients of aquafeed used for intensive and high intensive fish culture						
Wheat	16,5	87	10	1	4,5	Zheltov et al. 2003
Soy meal	8	90	28	16	2,5	Zheltov et al. 2003
Sunflower meal	10	90	16	16	4,5	Zheltov et al. 2003
Fish meal	20	88	44	2	2,5	Zheltov et al. 2003
Meat meal	11	89	64	0	2,5	Zheltov et al. 2003
Protein-vitamin complex	20	89	97	0	N/A	Zheltov et al. 2003
Methionine	0,5	89	99	0	N/A	Zheltov et al. 2003
Ingredients of aquafeed used for extensive						
Wheat	30	87	10	1	4,5	Zheltov et al. 2003
Barley	10	87	8	2	4,5	Zheltov et al. 2003
Corn	25	87	8	4	4,5	Zheltov et al. 2003
Full fat soy	15	90	40	16	2,5	Zheltov et al. 2003
Sunflower meal	15	90	16	16	4,5	Zheltov et al. 2003
Blood meal	5	89	64	0	2,5	Zheltov et al. 2003
Nutritive value of zooplankton organisms						
Daphnia spp.	N/A	10,7	45	4,5	2,5	Chaplina et al. 1970
Moina spp.	N/A	12,8	68,6	22,13	2,5	Chaplina et al. 1970
Chironomid larvae	N/A	11,42	58	11,43	2,5	Chaplina et al. 1970
Cyclops spp.	N/A	7,3	69,3	14,8	2,5	Chaplina et al. 1970
Brachionus spp.	N/A	9,2	64,3	15,1	2,5	Chaplina et al. 1970
Diaptomus spp.	N/A	7,6	57,9	25,1	2,5	Chaplina et al. 1970
Detritus	N/A	13,2–18,5	5,5–7	2–4,5	4,5–5,5	Chaplina et al. 1970

The inventory data and adjustments based on regulation and standards for fish feed production. Evaluation of the fishmeal substitution was made on the background of practically possible substitution rates according to ISO 14044 SimaPro 7.2 software was used to calculate the inventory results.

For evaluation, first inputs and outputs for the main production element (pond), which is considered as separated system in this case, had to be identified. As main useful output of the system, according to ISO 14040–14048, ready product, fish is this case was considered and fish food was considered as the main input.

The aim was to evaluate the negative impact of the production cycle on the environment, resources demand and material inputs and outputs within set boundaries.

One metric ton of ready product (fish) out coming from the production system (pond) with qualitative characteristics defined with Ukrainian standards was considered as functional unit within this study.

All streams which are "transformed" into the functional unit (fish) were considered in the scope of presented study.

Production structure with boundaries set for this study is depicted on the fig. 2.

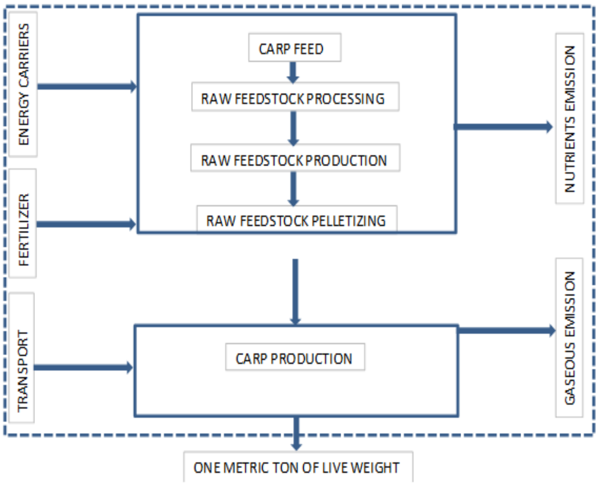

Fig. 2. Production structure with boundaries set for this study is depicted

Data for the LCA "tracked" to the primary resources, for instance for fuels and natural gas, used for aquafeed production, etc. "Load" associated with mining and processing was related to life cycle of energy carriers accordingly. Available data for life cycle of energy carriers consider all negative impacts including green house gases (GHP) emission, eutrophication (EP), acidic degradation (AP) water use, etc.

Primary activity data were used to quantify the direct inputs and outputs linked to the aquafeed facility.

As most important impact categories, GHG, EU and AD were identified. The potential of eco-toxicological potential on the human is not necessary to considered and thus it was not evaluated in the scope of this study, especially considering that rates of pesticides and heavy metals in pond ecosystem elements determined during this study according to existing standards were not exceeding maximal permitted concentrations.

According to CML 2001 method adapted to aquaculture within the set boundaries all functional connections within production system were defined and all empirical meanings were related to functional unit: one ton of fish at the farm gate. Farm data were collected from the direct measurement and farm surveys.

Generally accepted model for the calculations is based on multiple linear equations The solution was the amount, X (e.g., fish), of each activity i that produced the desired amount of output Z (e.g., ready market fish).

$$Z = \sum_{i=1}^{n} z_i x_i \quad ,$$

where Z_i is output for the production process i, which interacts with other production processes.

$$\sum_{i=1}^{n} C_{ij} X_i \quad = 0, j = 1 \dots p,$$

C_{ij} is supply or demand j for the process i, забезпечення чи потреба j для процесу i, demands are negative and supplies are positive.

The total amount of material M flowing into the system is expressed as

$$M_k = \sum_{i=1}^{n} m_{ik} X_i, k = 1 \dots q,$$

where m_{ik} – flow of the material k into the process i.

General impact of the system B for each particular category can be calculated as

$$B_l = \sum_{k=1}^{p} M_k b_{kl,} \; l = 1 \dots r,$$

where b_{kl} is the amount of burden l produced by the use or disposal of material k, and M*k* is the total amount of material.

The LCI identifies the contribution of each material, used during the production cycle as

$$B_{kl} = M_k b_{kl}$$

Nitrogen and phosphorus, that creating he burden were calculated as a difference between input (bulk amount of those in the aquafeed and fertilizers) and amount effectively used fish growth. Difference between those empirical meanings was considered and the air and water emission (ILCD handbook – Specific guide for Life Cycle Inventory data sets 2010).

GHG during vegetation of crops which were used as aquafeed raw materials were estimated from the amount of energy carriers required for seeding, culturing and harvesting summed up with the difference between areal sequestration of green house gases for the area used for the crop production versus the case of natural vegetation development. For the area occupied with ponds emission was not considered as this land used for agricultural purposes more than 20 years in row (UN Food and Agricultural).

Organic and mineral fertilizers added to ponds to boost fish yields by increasing primary productivity through released inorganic nutrients, or by providing organic carbon through heterotrophic pathways were considered as the potential source of direct ammonium and NOx emission and methane in case of organic fertilizer decomposition in water. Emission was calculated according to given in the literature coefficients for each type of fertilizers (ILCD handbook – Specific guide for Life Cycle Inventory data sets 2010).

Results and discussion

Field studies were conducted in summer and autumn during 2015 – 2017 years. Samples processing and analysis of the data was conducted in the laboratory fascicles of DSAEU. Natural food supply according to the rate of the development of water food planktonic and benthic organisms in studied ponds in general was on the sufficient rate and identified planktonic organisms belonged to taxa, which have nutritional value for carp.

Table 3

Natural food aquatic organisms development for studied ponds

	Bacteria plankton, g/m^3	Phytoplankton g/m^3	Zooplankton, g/m^3	Zoobenthos, g/m^2
Grow ponds	1,2–1,8	12–19	22–39	3,9–5,6

Obtained results comply with general nitrogen and phosphorous balance estimations and indicated sufficient rate of food supply for the fish, overall pond productivity was quite high (Zheltov, et al. 2013).

Water quality in ponds according to main hydro chemical characteristics met existing requirements for fish ponds (table 3).

Water hardness for studied water bodied were significantly higher of set limits which can be explained by regional water supply features in particular high salt content in ground waters in studied area.

Table 4

Water quality data for fish ponds obtained during study

Parameter	Permitted level for carp*	General permitted level	Spring 2015	Summer 2015	Spring 2016	Summer 2016	Spring 2017
2	3	4	6	7	8	10	12
T^{0}C	< 28					28,0	
pH	6,5–8,5	7,0–8,5	7,3	7,2	7,9	8,2	7,7
Dissolve oxygen, mg/l	> 5,0	6,0–8,0				6,48	
H_2S, mg/l	N/det.	N/det.	N/det.	N/det.	N/det.	N/det.	N/det.
NH_4^+, mgN/l	1,0	2,0	0,04	0,04	<0,1	0,11	<0,1
NO_2^-, mgN/l	0,1	0,1	0,5	0,05	N/det.	0,04	N/det.
NO_3^-, mgN/l	< 2,0	2,0	0,5	<0,5	<0,1	0,99	N/det.
PO^{-3}_4, mgP/l	0,5		0,05	0,05		0,09	0,71
$Fe_{\text{заг}}$, mg/l	1,0		0,03	<0,1		<0,05	
Ca^{2+}, mg/l	50–70				135,41	99,18	123,00
Mg^{2+}, mg/l	30				12,64	40,53	9,00
Hardness,Mg eq./l	5–7		7,8	8,9	7,80	8,28	7,80
Cl^-, mg/l	50–70				111,83	139,68	98,21
SO_4^{2-}, mg/l	50–70				538,04	232,19	488,98
Na^++K^+, mg/l	50				272,55		
Mineralization, mg/l	1000				1231,82	747,0	1138,9

Heavy metals content in water, bottom sediments and fish muscles were determined during this study. In pond water in Petrikivsky fish farm heavy metals content in all studied pond ecosystem elements did not exceed maximal permitted concentrations set for fish ponds. In one sample of carp muscles lead content slightly exceeded permitted level.

Chlorine organic pesticides were not detected in bottom sediments samples collected during this study as well as in pond water samples, only in one carp muscle sample γ – GHC was found in concentration 3,83 μg/kg.

In general three different techniques of carp production including all complex of measures applied for the carp farming process in the studied facility could be named – high intensive, intensive and extensive (table 3, 4.).

Table 5
General features of different carp production techniques implemented in the studied fish farm

	Mg, mg/kg	Zn, mg/kg	Cu, mg/kg	Fe, mg/kg	Cd, mg/kg	Pb, mg/kg
Slit	29,73	14,40	4,07	1,26	0,54	5,72
Water (summer)	0,055 MPL-0,01	0,031 MPL-0,05	0,010 MPL-0,001	0,096 MPL-1,0	0,032 MPL-0,005	< 0,0001 MPL-0,1
Water (Autumn)	0,534	0,015	0,012	0,117	0,007	0,053
Muscles (carp)	0,37 MPL-2	3,20 MPL-40	0,26 MPL-10	3,87 MPL-30	0,02 MPL-0,2	0,70 MPL-0,1
Muscles (carp)	0,24	3,79	0,49	7,82	0,02	0,45
Muscles (silver carp)	0,50	2,73	0,28	2,23	0,03	0,46

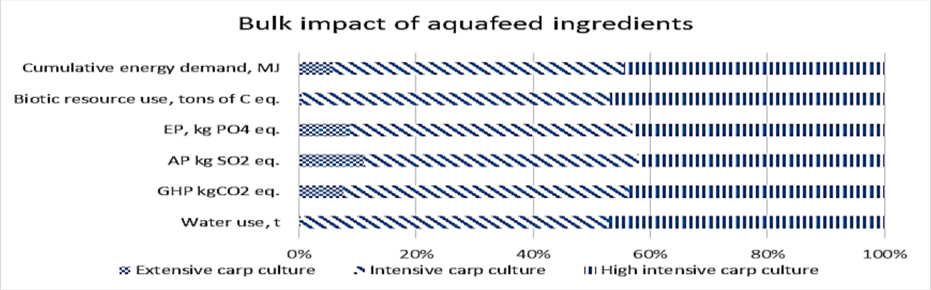

Fig. 4. Bulk impact of aquafeed ingredients related to one metric ton of fish produced with different culturing techniques

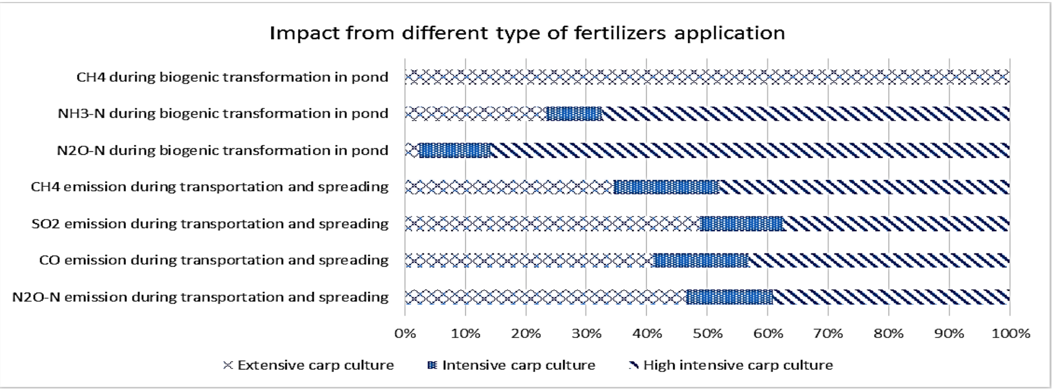

Fig. 5. Impact from different type of fertilizers application within different market carp production techniques related to 1 metric ton of obtained fish live weight

Main source of burden for the environment, created by the production cycle was connected with aquafeed use and also use of energy resources, water, biotic resources, required for aquafeed raw feedstock production in complex with aquafeed processing and missing itself.

All burden was calculated for case when all forage ingredients raw feedstock was produced and food processing facilities and transported with tracks to the fish farm.

After this processing, mixing and forming of aquafeed with further drying and storage was conducted on fish farm facilities. All energy carries required for such production and supply chain was related to the emission created by aquafeed use for the fish production process (fig 3, 1.). Obtained data demonstrate significant advantage of extensive carp production method in terms of resources consumption and emission created during production process.

Methane was found to be most significant air pollutant generating during organic fertilizers decomposition applied within extensive production cycle (fig. 4, 5.).

Our evaluation of emission indicates that main part of overall greenhouse gases emission (97 %) can be related to methane generation occurring form organic fertilizers decomposition in ponds. Fertilizers processing and application also contributes environmental impact significantly.

This questions overall sustainability of the production cycle as more in-depth studies are required to evaluate qualitatively and quantitatively emission occurring when organic fertilizers are applied directly into ponds.

Methane emission occurring after application of organic fertilizers, horse manure in this particular case, which is considered, appeared to be quite significant – 1,34 kg of GHG per metric ton of manure applied, although NH3 and NOx emission during application of mineral fertilizers is much higher – up to 60,5 kg per metric ton of applied fertilizers.

Transporting and application of fertilizers itself generates higher emission rates in case of use of organic fertilizers, which can be explained with relatively low concentration of mineral biogenic elements per bulk weigh of manure although their conversion to the product (fish biomass) appeared to be more effective.

Main resources for production are: agricultural land; water; solar irradiation; major biogenic elements (nitrogen, phosphorus, potassium, oligo-elements and micronutrients); fossil energy; ores and minerals used for production of machines and construction of buildings.

Biological cycle of fish pond requires constant input of carbon in form of CO2 an solar energy. Stable rate of nitrogen (N) and phosphorous (P) supply is required as well.

Obtained data compiles well with data of other researchers, which indicate that raw aquafeed feedstock production complete biggest share of environmental impacts is this sector.

Energy requirement for pond fish farming mainly connected with fish transportation and handling. Energy requirement depends strongly on farm location, size and design and used equipment type. Extensive carp cuturing requires significant accumulation of water, water use counted per unit of produces fishmeat is much higher than for intensive fishfarming techoogy. Big ponds used for fishfarming should be considered as important element of the environment and play important role in natural water turnover.

From the review of LCA studies the main environmental challenges for the three food supply chains have been highlighted and the most important issues can be assessed by LCA based methodologies and included in a simplified LCA web based tool. There are however environmental challenges that LCA methodology does not cover which are important to consider when assessing the environmental sustainability of a food supply chain, especially related to effects on biodiversity. Additionally there are other aspects and challenges that are not environmental, e.g. animal welfare and release of antibiotics to the environment, which are not possible to address with LCA methodology.

Conclusions

Development of market fish sector in current economical situation requires from aquaculture specialists in-depth understanding of technological processes and theoretical knowledge on aquaculture species biology, functioning of aquatic ecosystems, interaction between ecosystem elements and water environment and impact of technological elements on it.

Among all available categories of market carp aquaculture, which have environmental impact, following could be defined as significant:

- Global warming effects;
- Biotic deplention;
- Potential of environment degradation;
- Eutrophication.

On each of mentioned group switch to extensive aquaculture techniques provide certain improvement according to general analysis results.

Considering environmental burden created by production cycle is necessary to develop more sustainable production technologies competitive on the existing market.

Sustainability of the technological cycle in certain conditions of aquaculture farming and implementation of more environmentally safe techniques is necessary in the current situation.

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