

## NUTRITIONAL VALUE AND SAFETY OF AQUACULTURE PRODUCTS IN UKRAINE

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### Abstract

Modern aquaculture technologies allow to make the period of commercial ripening of fish 2 - 3 times shorter. At the same time there is an urgent problem of preserving nutritional value and hygienic safety. The study has a comparative analysis of relevant indicators of production at fish farms that are engaged in growing carp according to three most common in Ukraine technologies: pond, pasture, and closed cycle.

There have been used: materials of the State regional laboratory of veterinary and sanitary examination in Dnepropetrovsk, technological information of fisheries, information of Food and Agriculture Organization. The results of author's researches using the methods are presented: high performance liquid chromatography, gas chromatography, atomic absorption analysis.

The best indicators of the nutritional value are inherent to the products that have been grown according to pasture technology. The content of protein is 18.34 g, of polyunsaturated fat is 0.455 g in 100 g of the product. Products of the closed cycle are characterized by a high content of protein - 19.41 g and saturated fat - 0.425 g. In the products of pasture and pond technologies there has been found the permitted content of the maximum levels of heavy metals: Pb - 1.0 mg/kg, Hg - 0.6 mg/kg and pesticides: DDT and its metabolites - 0.3 mg/kg, thiazone - 0.5 mg/kg. Exceeding the permissible norms of antibiotics and hormonal drugs have been revealed in 27% of the samples of a closed cycle.

Keeping the revealed indicators in mind, the consumption of the investigated products by adults should be limited to 1 - 2 times per month, and children should be forbidden to consume these products. Contamination by pesticides requires some measures to be introduced in pasture and pond technology, as well as restoring the cancelled in Ukraine state veterinary control of technological processes for aquaculture.

**Key words:** *Aquaculture, Aquaculture technologies, Nutritional value, Hygienic safety.*

### 1. Introduction

Physiological needs will always remain the basis of the motivational pyramid. The constant growth of the human population, which over the last 50 years has increased more than two times and has made 7 billion people in 2011, has made the task of appropriate food and water providing a global problem. Specified demographic dynamics, as well as the extensive nature of the fisheries have led to the dramatic reduction in natural stocks of fish and other aquatic organisms. Awareness of the problem at the international and national level has occurred since the mid-twentieth century, as always postfactum when the volume of fish catch decreased significantly, and some species (e.g. sturgeon) were on the brink of extinction. The reaction of the world community, that was coordinated by the Food and Agriculture Organization (FAO) of the UN, has acquired forms of legal restrictions for the production of various types of marine resources (International Convention for the Regulation of Whaling in 1946, International Convention for the Conservation of Atlantic Tunas in 1966, Convention on International Trade in Endangered Species of Wild Fauna and Flora in 1979, Convention on the Conservation of Antarctic Marine Living Resources in 1980, Convention on the Law of the Sea in 1982, etc.).

Restrictions on fishing resources have given impetus for the development of aquaculture technologies and their implementation in the food production. According to the FAO, global proportion of fish for human consumption that was produced on technology of aquaculture increased from 7% in 1974 to 39 %

(73.8 million tons) in 2014 [1]. In Ukraine, the proportion of fish that was produced on technology of aquaculture in 2014 amounted to 30.1% (24.4 thousand tons) [2] (Sharylo Ju. Je. *et al.*, [3]).

Fish and food products derived from it are very important in ensuring a balanced diet. It is an accepted fact that fish products are a source of full value proteins and fats with a high content of polyunsaturated fatty acids. They, in turn, are a source of essential substances, which affect human health. The constant intensification of the fish production processes in aquaculture allows to reduce the aging period of the product 2 - 3 times. For example, the technology of closed units of a marketable carp weighing 400 g is grown in 280 days, and sturgeon, weighing 1 kg, in 365 days.

Aquaculture technologies involve the use of different methods for accelerating fish growth. Manufacturers that focus on environmentally friendly products try to provide accelerated growth, adhering to a certain temperature, providing saturation of water with oxygen, and maintaining the norms of the density of fish in the process ponds or reservoirs. The role of feed is crucial in the process of saleable product production. The most environmentally friendly method of feeding is the use of natural forage in open natural water ponds. However, most producers use a special vegetable and animal feed, the composition of which is very diverse. They are made by specialized manufacturers according to the science-based recipes. Appropriate aquaculture technologies provide active use of not only animal feed of plant and animal origin, but also: artificially synthesized drugs, including antibiotics, hormonal additives, fertilizers, pesticides.

Accelerating time of commodity aging by active use of modern chemistry and pharmacology products makes the problem of maintaining the nutritional value and safety of aquaculture products in Ukraine and world-wide relevant.

The aim of the study was to establish the values of indicators for food value and safety of products of fish farms engaged in growing carp on the three most common in Ukraine technologies: pond, pasture, closed cycle, or more precisely: 1. Analysis of nutritional value and safety of the used in fish farms feed; 2. Determination of compliance of the studied indicators with the existing state standards; 3. Development of recommendations on the safety of relevant products consumption and; 4. Optimization of manufacturing cycles of growing carp in aquaculture conditions by Ukrainian households.

## 2. Research of aquaculture production

### 2.1 Methods of research on aquaculture products

Indicators of the nutritional quality and safety of feed used in fish farms for the cultivation of carp were

determined according to the methods established by existing Ukraine standards. Appropriate methods are used in the process of planned and verification inspections of agricultural raw materials and animal feed by the State Regional Laboratory for Veterinary and Sanitary Examination in the city of Dnipro.

Sampling of feed for growing carp on technology of aquaculture was carried out in the warehouse of a trade company. There were taken 5 spot samples from 10 different packages of feed from one manufacturer and there was formed the average sample, which was the material for the investigation [4]. To determine the content of crude protein, a titrimetric method for the determination of nitrogen and calculation of crude protein according Kjenldal is used [5]. The determination of crude fibre is made according to the method of intermediate filtering [6]. Content of amino acids is determined according to the method of high performance liquid chromatography [7]. Content of calcium (Ca) is determined by titrimetric method [8]. Phosphorus (P) content is determined according to spectrometric method [9]. The amount of exchange energy is provided according to the information of commercial marking. Content of heavy metals is determined by atomic absorption analysis using atomic absorption spectrophotometers [10]. The residual amount of pesticides in the feed is determined by the gas chromatography on the gas chromatograph [11]. Determining the quantity of mesophilic aerobic and facultative anaerobic microorganisms is carried out according to the pour plate method and method for determining the most probable number.

Samples of live fish products were taken in the process of carps receiving consignment at the trading company in the city of Kryvyi Rih during September - October 2016. There have been formed 30 average samples of products grown on pond, pasture and by industrial technologies [12].

Determination of protein, fat and microelements has been carried out by the method of spectroscopy in the near infrared region [13].

Indicators of microbial contamination were established by the method of determining quantity of mesophilic aerobic and facultative anaerobic microorganisms by seeding in nutrient medium [14]. The number of coliform bacteria, coagulasepositive staphylococci, pathogenic microorganisms, as well as *Listeria monocytogenes* and *Salmonella* spp. by culturing in a respective, selective agar nutrient mediums, and by most probable number method [15]. The content of heavy metals is determined by atomic absorption analysis using atomic absorption spectrophotometers [16]. The content of pesticide residues is determined by gas chromatography [17]. Detection of antibiotics in the samples of carp meat is based on the analysis

of suppression of dehydrogenases activity of test cultures in a liquid nutrient medium. Hormonally remnants of drugs are determined by high-performance liquid chromatography.

## 2.2 Content of the aquaculture technology

The use of aquaculture technologies is governed by the Law of Ukraine "On aquaculture" [18]. Pond aquaculture technology has become the most widespread in Ukraine. It provides for the maintenance and rearing by using special fish feed in ponds and artificially created water bodies separated from the natural water bodies and in estuaries, flooded quarries, etc. Pond aquaculture started to develop in Ukraine since the 30s of the last century. The material basis for the spread of this technology is a large number of ponds suitable for freshwater fish breeding. According to the State Water Resources Agency of Ukraine about 50 thousand ponds can be used for growing fish by aquaculture technologies (Sharylo Ju.Je. *et al.*, [19]). Fish productivity of water reservoirs depends on the: hydrochemical and thermal regimes, degree of silts, density and nature of location of soft and hard water vegetation, and water-level fluctuations. In conditions of intensive technological exploitation, fish productivity of water bodies is continuously decreasing. To maintain an efficient economic level and provide high quality products the composition of pond aquaculture technologies for fisheries is supplied with agents of piscicultural amelioration, aimed at improving pond's physical, chemical and hydrobiological conditions, which should ensure rapid and full development of the fish.

Technical measures of fishery amelioration aimed at: ensuring the required level of water, its aeration, and support of the optimal water exchange, removal of reservoirs of the rigid water vegetation, reduction of silts. Agrobiological measures is ensuring improvement of water and soil conditions. They stipulate liming on the soil and water to remove the acid reaction of the soil, accelerating mineralization of organic substance and the release of soil carbon dioxide, creating favorable conditions for vital activity of microorganisms, which is of primary importance in ensuring the cycling of nitrogen, phosphorus and other nutrients in the pond. The most effective method of prevention and elimination of fish diseases is considered to be summer drying of ponds, which is held once every 5 - 6 years. After the autumn emptying and fishing off, the pond is drained and left till the next autumn without water. Freezing of the pond bed in winter and drying it in summer with simultaneous application of mineral fertilizers, pesticides and disinfection, ensure the formation of favorable hydrobiological condition. Summer drying allows you to destroy eggs and cysts of pathogens that are accumulated on the pond bed during several years.

The main objective of fertilizer application is the enrichment of water by nutrients and creating an environment in which there is the maximum development of primary production in the form of bacteria and algae, which is food for zooplankton and benthos that feed the cultured fish (Kononenko R. V. *et al.*, [20]).

Pond cultivation of carp suggests the use of several types of ponds. According to their functional purpose ponds are divided into: female fish, wintering, fingerling, rearing, feeding.

Pasture technology involves the aquaculture cultivation in objects and in natural conditions, through the introduction of mixed-age groups of aquatic animals produced under conditions of aquaculture, in fishery water bodies using natural forage. The main technological objective is the reconstruction of the fish fauna with the selection of fish polyculture, which efficiently use the forage base of the reservoir. Carp is the species that uses reproductive forage base of freshwater in Ukraine.

Part of the farms that use pasture technology for carp cultivation, have the above activities of fish amelioration with the aim of preserving the essential trophic and ensuring favourable hydrological state of the water body.

Technology of the closed cycle (industrial) provides artificial breeding, keeping and cultivation of fish using pools, installations of circulating and closed water supply. Industrial technology is based on the cultivation of fish at high stocking density by creating favourable culture conditions, feeding with a special food, mechanization and automation of all production processes. Goods are produced throughout the year. The productivity of industrial fish farms exceeds pond farms 10 - 20 times. However, introduction of appropriate technology requires large capital investments, which in conditions of permanent economic and financial crisis is very problematic. Therefore, an industrial complex of fish farms of Ukraine is represented by farms, activities of which were initiated in the period of planned economy.

According to the State Agency of Fisheries of Ukraine national fisheries complex includes 7850 water reservoirs with a total area of 108,689 ha. The object of the study was production of fish farms localized in Dnipropetrovsk region of Ukraine. This regional fishery complex consists of 230 ponds with a total area of 6,241 ha. In the region fish farming involves 225 farms of different legal forms [21].

In terms of production volumes farms can be divided into: large square water reservoirs from 270 to 50 hectares (LLC "Elegiya", LLC "Firma VV", "Zelenodolskryba", etc.), average - from 49 to 10 hectares (LLC "Nikopolkyi rybokombinat", "Brygantyna", "Slavutych", etc.),

and small - from 9 to 0.8 ha (Farm Enterprise "Mriia", LLC "Dniproagroprom", etc.). Small businesses (90%) are individual farm enterprises. 42% of the area of the ponds account for large enterprises, 26% for average, and 32% for small. Volumes of production of live carp on technological grounds in Ukraine and Dnipropetrovsk region are calculated on the basis of materials of the State Statistics Service of Ukraine [22, 23] and are shown in Table 1.

Average for the period of 2014 - 2016 shares of the total volume of carp rearing according to the pond, pasture and industrial technologies in Ukraine are, respectively: 92.7%, 1.4%, 5.8%. In Dnipropetrovsk region: 86.9%, 2.2%, 10.9%.

European integration processes and attempts of Ukrainian producers to enter new markets determined the process of implementation in practice of enterprises management principles and tools of quality management set by international standards of series ISO 9000. However, if industrial enterprises of Ukraine are actively implementing practices of management system certification and production according to international standards, at the same time agricultural producers are doing it very slowly. Fisheries of Dnipropetrovsk region are not certified according to quality management standards that are harmonized with the international ISO 9000:2005, ISO 9001:2008, ISO 9004:2000, and ISO 22000:2005. These standards integrate the principles and tools of Hazard Analysis and Critical Control Point (HACCP), and a system of good practices: Good Agricultural Practice, Good Manufacturing Practice, Good Hygienic Practice, Good Laboratory Practice etc., described by Codex Alimentarius Commission [24].

## 2.3 The results of the study of feed quality and safety

The majority of fish products that are grown in aquaculture conditions, belong to the pond and industrial technologies. Appropriate technological approaches involve the use of special feed consisting by elements of vegetable and animal origin. Analysis of the available in the domestic market of Ukraine feed for pond freshwater fish rearing provided the opportunity to determine their general composition and biological value.

To ensure the balance of essential trace elements, the composition of the feeds traditionally includes:

- Sunflower cake and sunflower meal, linseed, and soybean.
- Peas, soy, lentils, beans, wheat, barley, and maize.
- Fish, meat, meat and bone meal, and blood meal.
- Yeast and yeast hydrolysis.
- Defluorinated phosphate.
- Sunflower phosphatides.

To improve the efficiency and digestibility of feed in the amount of 1 - 2% there can be added a mixture of: amino acids (lysine, methionine, cystine, tryptophan, and threonine), minerals (Ca, P, Na), vitamins (A, D3, E, C) and enzyme preparations. Feed manufacturers indicate that the inclusion of protosubtilin to the carp feed with an average weight of 200 g in the amount of 1 mg/kg increases the digestibility of the dry matter intake by 6%, fat - by 42%, and carbohydrates - by 12%.

Now in Ukraine there is a widespread practice of various growth stimulators use. Their composition varies and may include biologically active substances synthesized from plant products (katholiken) and hormones.

**Table 1. Volumes of carp rearing on the technology of aquaculture**

Technology of aquaculture	Volumes of carp rearing, tonnes											
	2014				2015				2016			
	Ukraine		Dnipropetrovsk region		Ukraine		Dnipropetrovsk region		Ukraine		Dnipropetrovsk region	
	t	%	t	%	t	%	t	%	t	%	t	%
<b>Pond</b>	9,131	92.1	157	87.1	9,110	92.9	162	86.8	8,463	93.2	137	86.7
<b>Pasture</b>	139	1.4	4	2.1	147	1.5	4	2	128	1.4	4	2.5
<b>Industrial</b>	644	6.5	20	10.8	550	5.6	21	11.2	490	5.4	17	10.8
<b>Total</b>	<b>9914</b>	<b>100</b>	<b>181</b>	<b>100</b>	<b>9807</b>	<b>100</b>	<b>187</b>	<b>100</b>	<b>9081</b>	<b>100</b>	<b>158</b>	<b>100</b>

**Table 2. The results of the study of the nutritional and energy value of feeds for carp**

Name of the indicator, units	Norm DSTU 8214:2015 [25]	Sample 1	Sample 2	Sample 3	Sample 4
<b>Crude protein, %</b>	26.0 ≥	27.7	29.8	23.9	25.3
<b>Crude fiber, %</b>	≤ 6.0	4.8	5.1	6.9	6.5
<b>Lysine, %</b>	1.0 ≥	1.3	1.1	1.4	1.2
<b>Methionine + Cysteine, %</b>	1.0 ≥	0.87	0.9	0.8	0.9
<b>Ca, %</b>	≤ 1.4	0.3	0.8	0.6	1.7
<b>P, %</b>	1.0 ≥	0.5	0.8	0.4	0.9
<b>Exchange energy, MJ/kg</b>	~*	10.2	12.1	10.8	10.9

\*amount of exchange energy isn't regulated by relevant in Ukraine standards.



Approximately 95% of the feed, which is presented in the domestic market is produced in Ukraine. Analysis of forage market in Dnipropetrovsk region indicates that among the largest manufacturers and suppliers are: LLC "Konstanta", LLC "Agrozoosvit", "LLC "O.L. KAR.", LLC "GNK-GRUPA". The results of the study of indicators of nutritional and energy values of feeds that are produced in Ukraine presented in the domestic market, and designed for feeding marketable carp with the weight of 400 - 800 g during one year, are shown in Table 2.

Norms of indicators of nutritional value are determined in DSTU 8214:2015: Feed for different age groups of carp: Specifications [25]. The results of the analysis of the nutritional value of Ukrainian feed allow us to conclude about only a partial compliance with the relevant standards. Half of the investigated samples do not meet the standards for: protein, amino acids and phosphorus (P). At the same time there are high concentrations of fibre and calcium.

In the domestic market of Ukraine there are individual items of imported feed. For example, French firms "Aller Aqua" and "Skretting", Danish "Biomar", Dutch "Coppens" etc. imported feed have a higher nutritional value and cost. So, the average number of proteins, fats and carbohydrates in the imported feed is respectively: 37%, 12%, 31%. The total amount of metabolic energy is 15.5 MJ/kg. In the Ukrainian feed the average amount of proteins, fats and carbohydrates reaches: 26.7%, 10%, 23%, and the amount of exchange energy is 11 MJ/kg. At the same time the cost of imported feed is in the range from 7 to 20 euros per kg, which is 3.5 - 5 times higher than the cost of Ukrainian products. The importance of the cost of production in the competitive struggle for customers leads to the choice of producers in favour of the Ukrainian feed.

Not a less important factor influencing the quality of fish products that are grown on the technology of aquaculture is feed safety, which is understood as the absence of: toxic, carcinogenic, mutagenic, or other adverse effects of the products on objects of aquaculture. Accumulation in the commercial aquaculture production of substances that have the equivalent effect is potentially dangerous for consumers of such products. In Ukraine the permissible norms of hazardous

substances are approved by the order of the Ministry of Agrarian Policy and Food "On Approval of the List of Maximum Permissible Levels of Undesirable Substances in Feed and Raw Materials for Animals», which is harmonized with international standards [26].

The results of the study of indicators of safety of Ukrainian animal feed, which are presented in the domestic market according to the contents of toxic substances, is given in Table 3.

According to the study, the exceedance of established norms of toxic substances content has not been revealed. At the same time, the maximum permissible content of heavy metals Pb and Hg - draws attention and causes concern. Their presence at an almost high permissible level is due to the poor state of the environment, and the harmful effects of mining-ore and steel industry in the environment of: Dnipropetrovsk, Zaporizhia, and Donetsk regions, which are traditional suppliers of: wheat, barley and corn. A high permissible content of nitrite indicates the intensive use of nitrogen fertilizers in the cultivation of agricultural products.

Ukraine is one of the world leaders in the production and export of grain and leguminous crops. Collecting annually more than 60 million tons, to ensure the high performance of their farms, Ukrainian farmers are forced to use different classes of pesticides. The accumulation of pesticides in agricultural raw materials and the environment is a significant risk factor for the health of the population. Pesticides encourage the growth of: allergic, infectious, reproductive and cancer incidence. In Ukraine the officially approved for use in agriculture are 89 pesticides belonging to the following classes: insecticides, acaricides, fungicides, preparations for seed treatment, and herbicides. Established by regulations the maximum permissible level of pesticide residues in agricultural commodities and feed is 0.05 to 0.2 mg/kg [27].

The study of forage production samples from Ukrainian producers have shown no excess of admissible norms of pesticides. There were also established the positions for which pesticide residues equal to the maximum permissible indicators: camphechlor - 0.05 mg/kg, DDT and its metabolites 0.05 mg/kg, thiazone - 0.05 mg/kg.

**Table 3. Contents of toxic substances in the feed for carp rearing**

Name of the indicator, unit	Norm of the permissible contents [25]	Sample 1	Sample 2	Sample 3	Sample 4
As, mg/kg	≤ 4	2.2	3.4	3.5	2.4
Cd, mg/kg	≤ 0.3	0.1	0.3	0.3	0.2
F, mg/kg	≤ 350	230	250	320	240
Pb, mg/kg	≤ 5	4.8	4.9	4.6	4.7
Hg, mg/kg	≤ 0.2	0.2	0.2	0.1	2.0

A separate indicator of the carp rearing feed safety is the content of microbiological contaminants, which are the causative agents of dangerous diseases. The results of the study for relevant indicators showed compliance with regulatory requirements [26]. The total microbial contamination of feed is in the range from  $2.4$  to  $4.3 \times 10^5$  CFU in 1 g. The number of enterobacteria is from 140 to 300 in 1 g. *Salmonella* spp., pathogenic strains of *Escherichia coli*, sulfur reducing clostridia, pathogenic *Yersinia* spp., and coagulase-positive *S. aureus* have not been not detected.

## 2.4 Results of the study of nutritional value and safety of fish products

Chemical composition of fish products defines its potentially high nutritional value. Traditional indicators of nutritional value of products are the content of substances that provide the human body with necessary elements for the full course of all biological processes. These include: proteins, fats, minerals, vitamins and extractives. Particularly important are items that are not produced by the human body and enter it only with food.

Fish proteins are mostly of full value: albumins and globulins (simple proteins), and nucleoprotein, phosphorodiamidic and glycoprotein (complex proteins). Muscle tissue of fish contains 85% of proteins. They are almost entirely (97%) absorbed by the human body. Therefore, fish is a source of protein nutrition. The range of protein content in the carp meat is in the range from 12 to 19%.

Fish fat contains a large amount of unsaturated fatty acids (linoleic, linolenic, arachidonic, etc.), it has a low melting temperature (below 37 °C) and is easily absorbed by the human body. The carp belongs to the class of medium-fat (5 to 15% fat) fish.

Minerals are in the composition of proteins, fats, enzymes and fish bones. Most of them are in bones. These are: calcium salts, phosphorus, potassium, sodium, magnesium, sulphur, chlorine, and microelements: copper, cobalt, manganese, bromine, and fluorine.

Fish is an indispensable natural remedy for vitamin deficiency, because it contains vitamins: A, E and B, as well as vitamin D.

Extractive substances are in small quantities and are easily soluble in hot water. They flavor fish and broths with a specific taste and aroma, contribute to the stimulation of appetite and digestion.

Normative documents that are current in Ukraine as for the list of indicators of carp nutritional value regulate the amount of fat (5 - 15%), as well as the presence of minerals: calcium, magnesium, phosphorus and iron [28].

The averaged results of the study of indicators of nutritional value of carp meat that was grown by fish farms in Dnipropetrovsk region of Ukraine, grouped by type of the used aquaculture technology, are presented in Table 4.

The results of the study demonstrate that carp meat, which was grown on aquaculture technology partially loses its nutritional characteristics. Especially it refers to the contents of polyunsaturated fats. The figures obtained are in the range that belongs to the class of low fat fish, although in standard classification carp refers to medium-fatty. The highest content of proteins has been found in the meat of carp that has been grown according to the technology of the closed cycle in the pools, or special containers. The use of feed with a high content of: amino acids, fibre, enzyme preparations, and, as shown by tests, the use of hormones leads to activation of the formation of muscle tissues and increased protein content in the body of a carp. At the same time, the production of the closed cycle is characterized by the lowest content of polyunsaturated fats, which makes it less useful given the nutritional value. The best indicators of the nutritional value are in the products that have been grown on pasture technology. The content of protein is 18.34 g, and polyunsaturated fat - 0.455 g per 100 g of product weight. Low in fat, containing essential fatty acids leads to the exclusion of the samples of carp meat from dietary products.

**Table 4. The results of the study of indicators of nutritional value of carp meat**

Name of the indicator, unit	Content norm, regulatory document [27]	Content on aquaculture technology		
		Pond	Pasture	Closed cycle
Content of protein, g per 100 g of product	not regulated	17.67	18.34	19.41
Fat content, g per 100 g of product	5 - 15	1.535	1.635	1.485
Polyunsaturated fats	not regulated	0.395	0.455	0.365
Saturated fats	not regulated	0.465	0.345	0.425
Monosaturated fats	not regulated	0.675	0.835	0.695
K, g per 100 g of product	not regulated	2.2	2.1	2.4
Ca, g per 100 g of product	not regulated	0.3	0.2	0.3
Mg, g per 100 g of product	not regulated	0.4	0.3	0.4

Safety of aquaculture products is determined by the compliance of the indicators of content or the presence of hazardous substances in the meat of carp. Legally regulated are standards of microbiological contamination and maximum high presence of toxic substances: Pb, Cd, As, Hg, Cu, Zn, pesticides, antibiotics, dioxins, and radionuclides [15].

The results of the study of the microbial contamination degree showed compliance to the established standards. Carp grown in aquaculture conditions had the level of general microbial contamination in the range from  $2.9$  to  $4.5 \times 10^4$  CFU in 1 g. Coliform bacteria, coagulase positive staphylococci, pathogenic microorganisms as well as *Salmonella* spp. and *Listeria monocytogenes*, living helminths and their larvae, that are dangerous to humans, have not been found.

The excess of toxic substances content can have a negative impact on the human body and causes a failure of internals (Cd, As, Zn, Cu), the destruction of the central nervous system and damage of the DNA biosynthesis mechanism (Hg, Pb), and development of malignant tumours. The averaged volume of toxic substances in the meat of carp grouped on technology of aquaculture are shown in Table 5.

In the production of pasture and pond technologies was established the content of the maximum amount of Hg and Pb. These heavy metals are most dangerous to the human body. The main reason for limiting the content of these metals in fish products that are produced on pond and pasture technology is a general pollution of the natural environment by products of activity of mining enterprises and metallurgical complexes. This situation provokes a high content of heavy metals in: soils, water bodies, and agricultural raw materials, which has a negative impact on the level of aquaculture products safety. At the same time it should be noted, that carps grown in a closed cycle have the lowest content of heavy metals.

Analyzing the level of safety and nutritional value of the investigated products of aquaculture, it is necessary to emphasize the need to limit its use by adults taking into account prevention of heavy metals accumulation, which content reaches maximum indicators

in the human body (lead, mercury). It should also be noted that the determined content of heavy metals exceeds the permissible limits for baby food: Pb - 0.5 mg/kg, Cd - 0.1 mg/kg, Hg - 0.15 mg/kg, As - 0.5 mg/kg [28]. Therefore, children should not be allowed to use products containing carp meat grown on technology of aquaculture in Dnipropetrovsk region of Ukraine.

Toxic effects of pesticides on the human body cause: inhibition of metabolic processes, diabetes and cancer. Current Ukrainian legislation prohibits the use of products that contain the most known forms of pesticides: aldrin, heptachlor, camblin, metafos, topos, fenton etc.

Rules of the permitted content of pesticides currently acting in Ukraine do not correspond the requirements of the European Union. Regulation of the European Parliament and of the Council no. 396/2005 establishes the list of 82 drugs. A large part of the standards for levels of pesticide residues in Ukraine and the European Union are not identical. Given the general direction to the for new markets by Ukrainian producers, there is a need in the harmonization of legislation with EU requirements.

From the number of allowed pesticides in samples of carp meat grown on pond and pasture technology there has been detected the maximum permissible concentration of DDT and its metabolites - 0.3 mg/kg, and thiazone - 0.5 mg/kg. Carp grown on the technology of the closed cycle had 2 - 2.5 times lower content than that of the mentioned pesticides.

Maximum content of pesticides can be explained by the following reasons. First, the accumulation of pesticides in soil and water bodies due to uncontrolled use of pesticides by agricultural producers. Second, the use of pesticides in the cultivation of leguminous crops included in the feed. Third, the use of pesticides in the preparation of the ponds for the pond technology. Forth, technological isolation of the closed cycle carp cultivation prevents the accumulation of pesticides in the respective aquaculture products.

DSTU 2284:2010 "Fish alive. General technical requirements", as the main document, establishing safety requirements of aquaculture products, prohibits the

**Table 5. Results of the study of indicators as for the presence of toxic substances in the carp meat**

Name of indicator, unit	Standard norm of substance, DSTU 2284:2010	Content of toxic substances on technology of aquaculture		
		Pond	Pasture	Closed cycle
Pb, mg/kg	1.0	1.0	1.0	0.7
Cd, mg/kg	0.2	0.2	0.2	0.2
As, mg/kg	1.0	0.8	0.7	0.6
Hg, mg/kg	0.3	0.3	0.3	0.2
Cu, mg/kg	10.0	8.0	7.0	5.0
Zn, mg/kg	20.0	12.0	14.0	9.0

content of antibiotics, namely chloramphenicol, sulfa drugs, bacitracin, and tetracycline. An identical prohibition, but considering the content of hormonal drugs in food products in Ukraine is contained in the State Sanitary Standards and Rules [29].

According to the results of the study, there has been found the presence of residues of tetracycline (0.02 mg/kg) and testosterone (0.015 mg/kg) in 27% of samples of products which were grown on the technology of the closed cycle in a special technology tanks (basins).

Joining the discussion about the possibility and necessity of the production of organic fish products (Vdovenko N. M. *et al.*, [30]), it should be noted that, given the overall state of the environment of Dnepropetrovsk region of Ukraine, which is characterized by maximum content of heavy metals and pesticide residues in soils, the ability to obtain products that meet the requirements for organic products is very limited.

### 3. Conclusions

- Aquaculture technologies, despite a high degree of production processes control, make it impossible to ensure the preservation of nutritional characteristics at the level of existing standards. Low in fat containing essential fatty acids makes it necessary to exclude the samples of carp meat from dietary products.

- The lack of certified quality management systems at fish farms, and state moratorium on inspections of control bodies of entities providing economic activity since 2014 cause the formation of improper practices of farming. To ensure the quality and safety of products it is required to restore the permanent state veterinary control of technological processes in aquaculture and fisheries certification under ISO 22000:2007.

- The presence of a maximum concentration of heavy metals (Pb, Hg) and pesticides (DDT, thiazone) in samples of fish that were grown on the pond and pasture technology is explained by the negative environment of agricultural land and requires the introduction of appropriate technological measures for reclamation of used lands.

- When saving the investigated practices and established benchmarks, the use of the investigated products of carp meat by adults should be limited to 1 - 2 times per month, with the total prohibition of the use of these products by children.

- Further research is required for the problems of ensuring the quality of products of other fish species grown in aquaculture conditions in Ukraine, as the question of correlation between environmental pollution and safety of aquaculture products and the definition of technological chains, which will ensure the preservation of its nutritional value and security.

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