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LAURA KARNAI, ISTVÁN SZŰCS

University of Debrecen, Hungary

PROFITABILITY ANALYSIS OF FISH PRODUCTION IN AN EXTENSIVE POND FISH SYSTEM: A HUNGARIAN CASE STUDY

Key words: fish farming, cost and revenue analysis, polyculture, pond fish production

ABSTRACT. The aim of this paper is to examine case studies of production parameters and cost/income relationships of extensive pond fish systems. There is a global increase in demand for food, which presents huge challenges for terrestrial and aquatic food production to ensure sustainability. With the rise of aquaculture, fish meal – free, cereal-based carp production is becoming increasingly valuable from the perspective of sustainability. In addition, based on its production volume, cereal-based carp production is the third most significant fish species in global terms, while carp is also dominant among fish species in Hungarian pond systems. Data collected during the analysis were processed using descriptive statistical methods. To analyse the efficiency of production, changes in income were examined using different combinations of production parameters and certain cost items (*ceteris paribus*). Based on the obtained results, it can be stated that, in the case of the modelled farm, a 0.56 thousand € per hectare income can be realised. The initial cost and average weight at the moment of sales can greatly influence the profitability of a farm.

INTRODUCTION

At a global level, industrial agriculture and intensive production, which is unsustainable in the long term, lead to social and environmental problems. As a consequence, one of the biggest challenges of our time is to ensure sustainable production and development, especially in agriculture, as the growing demand for food (in terms of quantity, quality and security) due to population growth can be satisfied by this sector [Takácsné 2015, Horn 2014]. Fish production is also facing this challenge, as the consumption of fish meat is a key part of human nutrition. It is a significant characteristic of production whereby all three pillars of sustainability can be observed simultaneously. Fish production is also important from an economic aspect because it produces high-protein foods and provides material for fishing ponds, as well as social employment in rural areas, thereby improving the role of the area in maintaining the population [SustainAqua 2009]. In addition, extensive pond farms provide a habitat for many animals and positively influence the surrounding areas, thus having high agroecological value [Sterniša et al. 2017].

The combined production of fisheries and aquaculture is characterised by a growing trend on a global scale, mainly due to the growth of aquaculture year to year (around 20% in the last 5 years). Aquaculture has been playing an increasingly prominent role in the sector for millennia, but only in the last three decades has it become a major sector in the fish product market due to stagnation in wild fish and increased costs for catching wild fish [O'Shea et al. 2019, FAO 2019]. Hungary has always played a prominent role in Europe's freshwater fish production due to its hydrographic characteristics, as its gross production reached a thousand tonnes of fish on a pond of 26.5 thousand hectares, of which 17.9 thousand tonnes were edible fish in 2018. Based on the production volume of classical polyculture extensive pond fish, the common carp is followed by the silver and bighead carp and their hybrids (1.4 thousand tonnes), grass carp (474 tonnes), European catfish (259 tonnes) and other fish [Bojtárné et al. 2019, Kiss 2019].

Fish meat production in aquaculture is a special sector of the food industry, which, in addition to its similarities with other livestock production sectors, is different in terms of several factors, as it is produced in an aquatic environment which is a complex system due to the interaction of many external and internal factors. Artificial fish production, which is becoming increasingly widespread on a global scale, is characterised by technological diversity, ranging from traditional pond fish farming to intensive, industry-independent, climate-independent production [SustainAqua 2009]. The fish production sector is remarkably diverse in Hungary, as traditional pond fish production can be observed at different levels of intensity, but intensive farm fish production is also increasing [Váradi 2001, Pintér 2010]. Carp production represents a significant volume in aquaculture both globally and at a European level as it ranks third in terms of volume by having produced nearly 4.5 million tonnes in 2015. Carp production is mainly concentrated on the Asian continent, such as China and Indonesia, which together accounted for 86.2% of total production in 2015. In contrast, the fish production of the European Union (EU-28) has only increased by 3.5% over the last 20 years, but its share in international production has fallen significantly. The specificity of carp production can also be found in the fact that breeding can either be performed in monoculture or polyculture. In the case of monoculture, only common carp is produced in the pond, while in polyculture, several noble fish species (e.g. grass carp, silver carp, catfish and zander) are placed in one pond unit, but the proportion of different fish species are developed in a way that mostly increase output (about 85%) and should originate from the carp. In European Union fish farms, 700 and 1,500 kg/ha of live fish can be realised on a yearly basis, which equals 1.000 kg/ha, while Hungarian output is lower, around 800 kg/ha [Popescu, Vasile 2015].

The majority of domestic fish production is provided by fish ponds, therefore, the increase in domestic fish production can be achieved by a more efficient utilisation of the biological production capacity of ponds, the reduction of feeding costs, an increase of output and more intensive production. Here, too, climatic and soil factors (pond soils) have a major influence on production results. Similarly, to the quality of land, the technical condition, quality and thus potential (natural and artificial) fertility of each pond is different, which fundamentally differentiates producers in the fisheries sector. Fishery production has many advantages and disadvantages both from a pond fish farm and national economic point of view. In the current economic climate, the cost of a fishpond ranges on a wide spectrum between 4.7 and 20.4 thousand EUR/ha [Szűcs et al. 2017]. Assuming average technology in Hungary, a full-fledged farm with a complete production structure, the yearly production value of a pond fish system was around 1.4-2.0 thousand EUR/ha in 2016. The investment needs of Hungarian pond farms are extremely high, 75-85% of which are provided by fish-ponds. Domestic pond fish farming is basically performed in a traditional three-year form of production, i.e., the fish is suitable for commercial trade by the autumn of the third year. When examining output, the amount of fish harvested must be distinguished from the yearly number of offspring (production = harvest – placement). In recent years, on a national average, placement per hectare in domestic pond farms was around 280-350 kg/ha, while growth rates were between 450-650 kg/ha. In most operating fish farms, achieving a 1.0-1.2 t/ha (10-12 cwt) output is considered a realistic objective [Szűcs et al. 2017].

The size and composition of the yearly production cost varies from farm to farm and year to year, depending on the technology used, the level and intensity of production, local conditions, equipment, labour supply, cost of labour, input prices, human and other factors. In recent years, the figures for the main EU producers of carp farms in Poland, the Czech Republic, Hungary and Germany show that variable costs accounted for 67% in Poland, 65% in Hungary and 61% in Germany. In Poland, 18% of total production costs were personnel costs, while in Romania and Germany this figure was 40% and 56%. Within material costs, the cost of feed was 52% in Romania and 48% in Poland, while in Germany it was less than 26%. In German farms, the profitability ratio was 28%, while the same value was -2% in Poland. It is important to note that the carp farm in Poland, unlike Romania and Germany, did not necessarily receive support. Without the subsidy, the margin would be -0,18 EUR/kg in Poland, -0,77 EUR/kg in Romania and -1,43 EUR/kg in German, on average [Turkowski, Lirski 2010, EUMOFA 2017].

In an average fishpond farm in Hungary, material costs have the largest proportion of the average cost of fish production (65-70%) of which reproductive material has the highest share (40-45%) (Table 1). This value is followed by personnel costs (12-15%). Considering average production conditions, cost-effective profitability may reach values between 15-45% on average in Hungary, which means that farms can generate a EUR 0.15-0.45 income with EUR 1 production cost. The yearly production cost, calculated based on 2016 prices, is around 1.1-1.4 thousand EUR/ha assuming a full-fledged pond farm. Here, too, the standard deviation is due to different pond characteristics (e.g. filling up the pond with a pump or with gravity), the prices of available input and various professional skills. It is also

Table 1. Average yearly cost structure of a complex pond fish production farm

Costs	Distribution [%]	
Material costs, of which:		65-70
– feed	25-30	
– reproduction material	40-45	
– water costs	5-10	
– manure	5-8	
– energy. other	5-15	
Personnel costs	12-15	
Cost of special tanglible assets	3-4	
Auxiliary costs	4-5	
Other indirect costs	5-10	
Overhead costs (farm/sectoral/economy)	10-15	

Source: [Szűcs et al. 2017]

common that, due to liquidity and working capital financing problems, certain technological elements (e.g. feeding) have not been adhered to accurately. Net income available in 2016 was approximately 156.8-470.4 EUR/ha, which is not considered to be competitive compared to arable farming on mid-quality arable land, also including area-based subsidies [Szűcs et al. 2017]. The aim of this paper is to study the production parameters, cost and income conditions of extensive polyculture carp pond farms, and the impact of changes in the most important economic and production parameters on various economic indicators, using a Hungarian case study. The goal was to compare the productivity and efficiency of Hungarian carp pond farms with international ones.

RESEARCH MATERIAL AND METHODS

Both primary and secondary data collection were performed during the analysis. During the preparation of the paper, it was also considered important to place the fisheries sector in an international dimension in order to gain a better understanding of the competitive advantage or disadvantage of Hungarian players. Part of the required data was collected from industry-specific materials (the Hungarian Aquaculture and Fisheries Inter-branch Organization), articles, international statistics and Hungarian databases both at a national and international level. In order to present the processes taking place on the world market of fishery and aquaculture products and on a European scale, databases and reports compatible with the FAO (Food and Agriculture Organization of the United Nations) EUROSTAT database were used. In the course of sectoral analysis in Hungary, several databases were used, among others the databases of the AKI (Agricultural Research Institute) and KSH (Central Statistical Office), as well as earlier published papers of Hungarian authors [Pintér 2009, Szűcs et al. 2017, Váradi 2001] on the fisheries sector.

During primary data collection, data on the entire breeding technology of an extensive polyculture pond farm in Hajdú-Bihar county was collected. In this process, various technological and economic data were also collected, and natural efficiency indices derived from production parameters were generated. Primary data collection was based on data from 2019. Focus was placed on production and technological parameters (farm size, fish production, change in animal stock, feed consumption), input and output prices and average cost items. The processing of primary data (technological parameters and basic economic data) and derived indicators was performed using descriptive statistical methods. Derived indices were determined for a full year for three pond units. The size of ponds and the amount of placement were determined with the assumption that 100 tonnes of carp would be sold by the end of the third year. The impact of changes in sales prices, feed prices and key production parameters (specific feed consumption, average weight at the time of sale) on various economic indicators were also examined. In the model calculation required for this calculation, the selling price of carp and the average weight at the time of sale as independent variables were considered. Fixed costs were distributed on an area basis and it was assumed that the production value of bycatch, which is harvested in addition to the main product, i.e. carp, equals the production cost. Subsequently, the main economic indicators of activity (unit income, prime cost) were examined as dependent variables and cross-tables were prepared to illustrate the obtained results.

RESEARCH RESULTS

The model calculation was based on a pond farm in the Hajdú-Bihar county. This farm is an extensive polyculture carp farm with three separate fishponds, which constitutes 137.5 ha of pond area altogether (Table 2). The water surface of pond 1 (T1) is 12 ha, that of pond 2 (T2) 51 ha, while pond 3 (T3) has a 74.5-hectare surface, and each fishpond contains only fish of the same age group. The fishponds on the farm are circular embankment type ponds, since it is the most common form of embankment in the North Great Plain region, with a depth of about 1.3 meters. Most pond farms only use one-meter depth ponds and wintering takes place in a wintering house. However, in this calculation, it was assumed that wintering takes place in the pond. i.e., this depth is essential to protect fish from freezing.

The peculiarity of the model is that production takes place in all ponds and, as a result, in all age groups at the same time. Juvenile fish are released in May and then transferred to the two-summer-old fishpond after the autumn harvest, where the breeding season begins after winter. Subsequently, two-summer-old fish are reclassified in November to pond 3 (T3), where they are harvested in the summer, but reach their market weight at the end of October, with an average weight of three kilograms for the autumn harvest.

The surplus from harvesting the various ponds is sold every year. As the main profile of the farm is carp production, this species is placed in the highest proportion so that the output increase (reproduction) for each of the three pond units is 1,000 kg/ha, of which common carp has an 85% share. that of grass carp is 10%, while the proportions of silver carp and catfish are 3% and 2%, respectively. In the case of feed, 1.56 kg of cereal-based wet feed (corn, wheat) is used to produce 1 kg of live carp. If the feed coefficient is set

Table 2. General characterisation of the model calculation

Description	Fishponds (codes)		
	T1	T2	T3
Pond area [ha]	12.0	51.0	74.5
Average depth of water [cm]	130	130	130
Proportion of species at the time of placement (common carp/silver carp/grass carp/catfish) [%]	85/10/3/2	85/10/3/2	85/10/3/2
Date of placement [month]	May	November	November
Average carp weight at the time of placement [g]	0.3	100	1,100
Date of harvesting [month]	October	October	October
Average carp weight at harvesting [g]	100	1,100	3,000
Specific organic manure use [t/ha]	13	10	8
Specific total output [kg/ha]	1,000		
Specific feed use [kg/ha]	531		
Feed coefficient [kg/kg]	1.56		

Source: own calculations

Table 3. Different production cost items of a carp pond farm

Description	Sector total [thousand EUR]	Cost per one hectare [thousand EUR]	Distribution [%]
Material costs	227.57	1.66	62
Personnel costs	68.20	0.50	19
Costs of special tangible assets	46.39	0.34	13
Total direct costs	342.16	2.49	94
Overheads	21.95	0.16	6
Total production costs	364.11	2.65	100

Source: own calculations

at 1.56 for an output of 850 kg carp per ha, the feed-based output will be 40% and the natural output 60%. The specific use of organic manure varies in each pond.

The production cost can be divided into different cost types (Table 3), which makes it easy to determine the percentage of each cost category contributing to the total cost, 94% of the production costs of the model pond farm are direct costs, which equals EUR 342.16 thousand (2.49 thousand EUR/ha) at a sectoral level. The basic assumption of the calculation is that the farm will be able to sell 100 tonnes of carp for the 3rd year, i.e., the material costs are different for the three ponds, taking into account the placement number and dropout rate and due to the prime cost variants in relation to reclassification. However, the total sectoral amount of production costs is EUR 227.57 thousand, making this cost item the most significant (62%) direct cost. In the case of material costs, the most important cost item is the cost of breeding material and water. Personnel costs (19%) are tripled in the harvest period as a result of increased work time. The total production cost of the farm is EUR 364.11 thousand per year, i.e. 2.65 thousand EUR/ha.

In determining the selling price, the average of the 5-year selling prices of the fish farm was used as a basis, considering the effect of the VAT reduction of fish products on the price. In determining the price for internal use (in the case of transfer), the prime cost was considered for the main products, while the market unit price was used for by-products. For by-products, it was assumed that their production value equals their costs. In terms of sales prices, it can be observed that the value of younger age groups is higher as their prime cost is also higher (Table 4). The planned pond farm's sales revenue is EUR 283.78 thousand per

Table 4. Farming results

Description	Sector total [thousand EUR]	Cost per ha [thousand EUR]
Revenue	283.78	2.06
Production value	441.74	3.21
Contribution margin	99.59	0.72
Net Income	77.63	0.56
Cost-effective return [%]	27.4	
Income level [%]	17.6	

Source: own calculations

year, 78% of which comes from the P3 age group. Considering these data, pond-based fish farming realised a net income of EUR 77.63 thousand (0.56 thousand EUR/ha).

It is important to note that this calculation does not count subsidies; it examines how profitable fish production can be without various subsidies. Supplementary income services and subsidies have a significant impact on the profitability of both domestic and European carp farming. Comparing the available data of main competitors (Poland and the Czech Republic), it can be established that profitability of carp farms was extremely variable, because the profitability of bigger farms was positive while many farms can achieve a negative result only without subsidies. Hungary's competitive disadvantage is not due to the high cost of production, but high logistic costs compared to other countries.

As a next step, with the help of model calculations, it was examined how a change in the selling price of carp, the average weight of sold carp and the cost of the two-summer-old carp affect the unit income and prime cost. Due to the sale of the main product, i.e. carp, sensitivity analysis was only carried out for the three-summer-old carp, while changing the factors that influenced the profitability of production the most in the performed calculation. The basic data of the model calculation (natural efficiency indicators, input-output prices and cost data per sector and per hectare) are fixed data input for sensitivity analysis.

The specific income of activity with different combinations of the selling price of the three-summer-old carp and the cost of the two-summer-old carp (*ceteris paribus*) were examined (Table 5). It can be concluded that the cost of 2.69 EUR/kg at the selling price of EUR 2.12 leads to a loss-making activity. At this selling price, the critical cost of carp is 2.685 EUR/kg. At the highest cost, a sales price above 2.168 EUR/kg is required for the activity to be profitable.

Table 5. Changes in specific income as a function of selling price and the cost of two-summer-old carp

Specific income [EUR/kg]		Selling price [EUR/kg]									
		2.04	2.12	2.20	2.28	2.36	2.44	2.52	2.60	2.66	2.82
Cost of two-summer-old carp [EUR/carp]	2.52	-0.013	0.067	0.144	0.222	0.301	0.379	0.458	0.536	0.614	0.771
	2.55	-0.025	0.055	0.132	0.210	0.289	0.367	0.446	0.524	0.602	0.759
	2.57	-0.037	0.043	0.120	0.198	0.277	0.355	0.434	0.512	0.590	0.747
	2.60	-0.049	0.031	0.108	0.186	0.265	0.343	0.422	0.500	0.578	0.735
	2.63	-0.061	0.019	0.096	0.174	0.253	0.331	0.410	0.488	0.566	0.723
	2.66	-0.073	0.007	0.084	0.162	0.241	0.319	0.398	0.476	0.554	0.711
	2.69	-0.085	-0.005	0.072	0.150	0.229	0.307	0.386	0.464	0.542	0.699
	2.72	-0.097	-0.017	0.060	0.138	0.217	0.295	0.374	0.452	0.530	0.687
	2.75	-0.109	-0.029	0.048	0.126	0.205	0.283	0.362	0.440	0.518	0.675
	2.78	-0.121	-0.041	0.036	0.114	0.193	0.271	0.350	0.428	0.506	0.663
	2.82	-0.133	-0.053	0.024	0.102	0.181	0.259	0.338	0.416	0.494	0.651

Source: own calculations

Table 6. Changes in specific income as a function of the average weight of sold carp and the cost of two-summer-old carp

Specific income [EUR/kg]		Average weight of sold carp [kg/carp]										
		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
Cost of two-summer carp [EUR/carp]	2.52	-0.788	-0.508	-0.275	-0.078	0.091	0.238	0.366	0.479	0.580	0.670	0.751
	2.55	-0.805	-0.524	-0.289	-0.091	0.079	0.226	0.355	0.469	0.570	0.660	0.742
	2.57	-0.823	-0.540	-0.304	-0.104	0.066	0.215	0.344	0.459	0.560	0.651	0.733
	2.60	-0.840	-0.556	-0.319	-0.118	0.054	0.203	0.333	0.448	0.551	0.642	0.725
	2.63	-0.857	-0.571	-0.333	-0.131	0.042	0.191	0.322	0.438	0.541	0.633	0.716
	2.66	-0.875	-0.587	-0.347	-0.145	0.029	0.180	0.312	0.428	0.531	0.624	0.707
	2.69	-0.893	-0.603	-0.362	-0.158	0.017	0.168	0.301	0.418	0.522	0.615	0.698
	2.72	-0.910	-0.619	-0.377	-0.172	0.004	0.156	0.290	0.407	0.512	0.606	0.690
	2.75	-0.927	-0.635	-0.391	-0.185	-0.008	0.145	0.279	0.397	0.502	0.596	0.681
	2.78	-0.945	-0.651	-0.405	-0.198	-0.021	0.133	0.268	0.387	0.493	0.587	0.672
	2.82	-0.962	-0.666	-0.420	-0.212	-0.033	0.122	0.257	0.377	0.483	0.578	0.664

Source: own calculations

Table 7. Changes in prime cost as a function of average weight of sold carp and the cost of two-summer-old carp

Prime cost [EUR/kg]		Average weight of sold carp [kg/carp]										
		2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
Cost of two-summer carp [EUR/carp]	2.52	3.077	2.797	2.564	2.367	2.198	2.051	1.923	1.810	1.709	1.619	1.539
	2.55	3.094	2.813	2.579	2.381	2.211	2.063	1.934	1.820	1.718	1.627	1.546
	2.57	3.111	2.829	2.594	2.394	2.223	2.075	1.945	1.830	1.727	1.635	1.553
	2.60	3.128	2.845	2.609	2.407	2.235	2.086	1.956	1.840	1.736	1.643	1.560
	2.63	3.145	2.861	2.624	2.421	2.248	2.098	1.967	1.850	1.745	1.651	1.567
	2.66	3.162	2.877	2.639	2.434	2.260	2.110	1.978	1.860	1.754	1.659	1.574
	2.69	3.179	2.893	2.654	2.447	2.273	2.121	1.989	1.870	1.763	1.667	1.581
	2.72	3.196	2.909	2.669	2.461	2.285	2.133	2.000	1.880	1.772	1.675	1.588
	2.75	3.213	2.925	2.684	2.474	2.297	2.144	2.011	1.890	1.781	1.683	1.595
	2.78	3.230	2.941	2.699	2.488	2.310	2.156	2.022	1.900	1.790	1.691	1.602
	2.82	3.247	2.957	2.714	2.501	2.323	2.168	2.033	1.910	1.799	1.699	1.609

Source: own calculations

In addition to the various combinations of the cost of two-summer carp and the average weight at the time of sale, changes in production parameters have a significant impact on the realisable income of the activity. With a given average weight at the time of sale, the improvement of the prime cost by 0.01 EUR/kg (*ceteris paribus*) reduces the prime cost and raises income per kg (Tables 6 and 7).

It is clear from the table that, as the average weight increases (*ceteris paribus*), the cost decreases continuously, and the unit income can be increased to various degrees. Between the two extremes of the combination of production parameters, there is a difference of up to EUR 1.5 in cost and income.

SUMMARY AND CONCLUSIONS

In the case of the model put together based on the collected data, the extensive pond farm sells approximately 100 tonnes of carp and 16.3 tonnes of bycatch on 137.5 ha in one year, also taking the dropout rate into account. The production of 1 kg of carp costs an average of 2.65 thousand EUR/kg, 62% of which constitutes material costs. After analysing the economic indicators, it can be concluded that extensive polyculture carp production can be considered economical, since the model yields a net income of 0.56 thousand EUR per ha, while the contribution margin is also favourable (0.72 thousand EUR/ha). Based on these data, it can be observed that realisable income is higher than that of many other arable crops, with a cost-effective return of 27.4%. As a result of the model calculation, it can be concluded that a 0.03 EUR/kg change in the cost of two-summer-old carp increases the prime cost by 0.017 EUR/kg and decreases the specific income by the same amount. However, a 0.1 kg change in the average weight at the time of sale constantly reduces the prime cost. Altogether, it can be concluded that the change in the initial cost and the average weight at the time of sale can greatly influence the profitability of a farm.

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ANALIZA RENTOWNOŚCI PRODUKCJI RYBNEJ W RAMACH EKSTENSYWNEJ GODPODARKI STAWOWEJ: WĘGIERSKIE STUDIUM PRZYPADKU

Słowa kluczowe: hodowla ryb, analiza kosztów i dochodów, polikultura, produkcja w stawach rybnych

ABSTRAKT

Celem artykułu jest studium przypadku w odniesieniu do parametrów produkcyjnych oraz relacji kosztów do dochodów w ramach ekstensywnej gospodarki stawowej. Obserwowany jest ogólnoświatowy wzrost zapotrzebowania na żywność, co wiąże się z wielkimi wyzwaniami w zakresie lądowej i wodnej produkcji żywności, w celu zapewnienia zrównoważonego rozwoju. Wraz z rozwojem akwakultury wolnej od stosowania mączki rybnej i opartej na zbożach, hodowla karpi staje się coraz cenniejsza z punktu widzenia zrównoważonego rozwoju. Dodatkowo, biorąc pod uwagę wielkość produkcji, hodowla karpi oparta na zbożach, zajmuje trzecie miejsce wśród hodowlanych gatunków ryb w ujęciu globalnym. Karp dominuje nad innym gatunkami ryb również w węgierskiej gospodarce stawowej. Dane zgromadzone w trakcie analizy przetworzono za pomocą opisowych metod statystycznych. W celu zbadania wydajności produkcji zbadano zmiany wielkości dochodów przez zastosowanie różnych kombinacji parametrów produkcyjnych i niektórych pozycji kosztowych (*ceteris paribus*). Na podstawie uzyskanych wyników, można stwierdzić, że w przypadku gospodarstw poddanych modelowaniu, możliwe jest wygenerowanie dochodu w wysokości 0,56 tys. euro w przeliczeniu na hektar. Koszt wstępny oraz średnia waga w momencie sprzedaży mogą mieć znaczący wpływ na rentowność gospodarstwa.

AUTHORS

ISTVÁN SZŰCS, ASSOCIATE PROFESSOR
ORCID: 0000-0001-8041-6636
University of Debrecen
Faculty of Economics and Business
Böszörményi St., H-4032 Debrecen 138
Hungary

LAURA KARNAI, PHD STUDENT
ORCID: 0000-0002-9216-6504
University of Debrecen
Faculty of Economics and Business
Böszörményi St., H-4032 Debrecen 138
Hungary