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The effect of the harvesting season on the use value and physicochemical properties of the meat of selected fish species reared in Polish aquaculture

Agnieszka Kaliniak[#]

University of Life Sciences in Lublin, Faculty of Biology, Animal Science and Bioeconomy,
Institute for Quality Assessment and Processing of Animal Products,
Department of Commodity Science and Processing of Raw Animal Materials,
ul. Akademicka 13, 20-950 Lublin, Poland; [#]e-mail: agnieszka.kaliniak@up.lublin.pl

The objective of the research was to evaluate the impact of the harvesting season on the value in use and physicochemical properties of the meat of selected fish species reared in Polish aquaculture. The study was conducted on five species: rainbow trout, common carp, grass carp, pike and tench. Fish were obtained from farms located in the Lublin Voivodeship in two seasons (spring/summer and autumn/winter). Morphometric measurements of the fish were performed, the percentage shares of body parts were assessed, and the physicochemical properties of the muscle tissue were measured: pH, electrical conductivity, water holding capacity, and CIE L*a*b* colour characteristics. The harvesting season significantly affected the body weight of carp, rainbow trout and pike, the maximum body height of carp and rainbow trout, and the total length and head length of pike. Pike, grass carp and tench had significantly lower Fulton's condition factors in the autumn/winter season than in the spring/summer season. The season significantly influenced the share of viscera in rainbow trout and grass carp, and that of fins in carp and rainbow trout. A significant impact of the season was also noted in the case of pH in rainbow trout and tench, electrical conductivity in trout, pike and tench, and the M/T ratio in grass carp and tench. Chromatic parameters differed significantly between seasons in pike (a*) and in carp and rainbow trout (b*).

KEY WORDS: fish, fishing season, physicochemical properties, morphometric measure ments, value in use

Fish are among the food products most highly recommended by dietitians, because they are a valuable source of essential unsaturated fatty acids (including omega-3 and omega-6), easily digestible protein, and minerals [3]. Despite their nutritional and health-promoting properties, fish remain undervalued by the Polish consumer. In 2016, per capita consumption of fish (together with seafood) in Poland amounted to 13.11 kg [21]. Recommendations for rational nutrition indicate that fish should be eaten at least

twice a week [7], while the average Polish consumer has a fish dish or snack less than once a week [22].

Because the seas and oceans are not an inexhaustible source of food, and the increasing level of salt water pollution raises concerns about the quality of food obtained from them, aquaculture has become a rapidly growing sector of the agri-food industry around the world [25]. In 2014, nearly half of the fish intended for human consumption worldwide came from aquaculture. It is estimated that by 2030 the share of aquaculture in world production will be 62% [8]. In Poland, the share of aquaculture in domestic fish production does not exceed 20%. Two species, common carp and rainbow trout, are of primary importance. In addition, species such as silver carp, bighead carp, grass carp, tench, pike, European catfish, crucian carp and zander are raised in polyculture with common carp in earthen ponds [13, 14, 17].

The quality, chemical composition and dressing percentage of fish meat are determined by a variety of factors, which include environmental conditions, physiological state, sex, age, and harvesting season [26]. The value in use of fish consists of qualitative and quantitative features, including the share of edible parts and the nutritional value, associated with their chemical composition, energy (calorific) value and nutritional density [23].

The aim of the study was to assess the effect of the harvesting season on the use value and physicochemical properties of the meat of selected species of fish raised in Poland.

Material and methods

The research included five species of Polish aquaculture fish: rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*), pike (*Esox lucius*) and tench (*Tinca tinca*). Fish were obtained at fish farms located in the Lublin Voivodeship in two seasons, spring/summer (April to September) and autumn/winter (October to March).

After the fish were caught they were stunned (mechanically or electrically) and immediately sacrificed (by severing the spinal cord), and then their body weight (W) was determined to within 0.1 g.

Assessment of the value in use of the fish included the following morphometric measurements (accurate to within 0.1 cm) made using a ruler:

- total body length (Tl)
- maximum (H) and minimum (h) body height
- head height (hh) and head length (lh) [2]

The initial processing of the fish included descaling (removing the scales from the skin), gutting (opening of the body cavity and removing the viscera and blood clots) and finning (cutting off the caudal, dorsal, thoracic and abdominal fins at a distance of about 0.5 cm from the base).

Based on the total length and weight of individual fish, Fulton's condition factor [9] was calculated according to the formula $F = (W \times 100) \times Tl^{-3}$. After initial treatment, the indivi-

dual body parts, i.e. the viscera, fins, skeleton (all bones), skin and fillet (skin and meat), were weighed and their percentage shares were determined.

The study was conducted on 150 fish (30 fish of each species) in two seasons (15 fish per species in each season). Samples for chemical analysis were taken from the dorsal muscle.

Active acidity (pH) was determined directly in the dorsal muscle using an Elmetron CP-401 waterproof pH meter and ERH-12-6 combination electrode, and electrical conductivity (EC, mS cm^{-1}) using a PQM I-KOMBI apparatus (INTEK GmbH, Aichach, Germany). The water-holding capacity of the meat was determined by the filter paper method [11]; 300 mg of each sample of ground fish meat was weighed out and placed on Whatman no. 1 filter paper under a constant pressure of 2 kg for 5 minutes. The area (cm^2) of the meat sample (M) and the total area of wetted paper (T) was determined by measuring image scans made with MultiScan Base computer image analysis software v. 14, and the results were expressed as M/T × 100. Colour was assessed n the CIE L*a*b* system (where L* - lightness, a* - red saturation, b* - yellow saturation) on the inner surface of the freshly obtained fillet using a Minolta CR-310 colorimeter (Minolta, Osaka, Japan) [4]. All physicochemical properties were measured 24 hours post mortem.

Statistical analysis of the data was performed using STATISTICA 13 software [6]. Due to obvious interspecies differences, the analysis was limited to comparison between seasons within each species. The tables present the mean and standard deviation for biometric measurements, use value parameters and physicochemical properties, and the differences between seasons were verified using Student's t-test for independent samples, at $P \leq 0.05$ and $P \leq 0.01$.

Results and discussion

In the autumn/winter season, carp and rainbow trout had significantly higher total weight ($P \leq 0.05$) and maximum body height ($P \leq 0.01$) than in the spring/summer season, and in the case of rainbow trout, greater head height as well ($P \leq 0.01$; Table 1). In the same season, i.e. autumn/winter, pike had significantly lower body weight ($P \leq 0.01$), as well as lower total length, head length and head height ($P \leq 0.05$), and thus also a significantly inferior body condition ($P \leq 0.01$) than fish of this species obtained in the spring/summer season. Significantly lower values for Fulton's condition factor in the autumn/winter period were also found in grass carp ($P \leq 0.01$) and tench ($P \leq 0.05$).

The harvesting season also significantly influenced the percentage share of certain body parts of the fish species (Table 2). In the autumn/winter period, the share of viscera was significantly lower in grass carp ($P \leq 0.01$) and significantly higher in rainbow trout ($P \leq 0.01$) than in representatives of these species obtained in the spring/summer. In rainbow trout and carp, the share of fins was significantly lower ($P \leq 0.01$) in the au-

tumn and winter months than in the spring and summer. Jobling [15] reports dressing percentages ranging from 30% to 40% for catfish and 50% to 65% for salmonids. This parameter is determined by many factors, including – in addition to nutrition, genetic background, sex and unit weight – the harvesting season. Białowąs [1] estimates the impact of each factor on the slaughter value at 2% to 5%. Trbović et al. [27], assessing the weight of carp during semi-intensive farming, found significant differences between months: April – 598 g, June – 874 g, September – 1439 g, and October – 1984 g. Grela et al. [12] found similar average dressing percentages in fish species (carp 71.2%, bream 73.2%, pike 76.8%, zander 73.3%). Skałecki et al. [24] also showed no significant differences in the weight and body length of wild perch between seasons. The season also did not significantly affect their body condition or value in use, although a higher share of meat was recorded in spring (by 3.15%) as compared to individuals caught in autumn. Dąbrowski [5] found significant differences in the body length and weight of salmonids from Lough Neagh depending on the month of harvesting, as well as in the percentage share of fillet and the condition factor. The greatest body length was noted in these fish in December. The highest female body weight was also recorded in December, while males had high body weights from June to December. The lowest condition factors and proportions of fillet were observed in January. The author suggests that these differences were largely determined by the breeding cycle of the fish species (*Coregonus pollan*, Thompson).

Zakęś et al. indicate the breeding season as an important determinant of slaughter value [28]. They showed that the share of fillet with and without skin in pike harvested in autumn (before spawning) was significantly higher, by 7.5% on average, than in specimens harvested in spring (after spawning). Pike muscle weight in the spring was significantly lower, which according to the authors is explained by energy expenditure during spawning migrations and spawning itself. In addition, fish during this period appeared to be 'more difficult to process,' and the level of losses during processing was higher (2.3%) than for individuals obtained in the autumn (0.7%).

In our study, the percentage share of the fillet of the fish species was lower in the autumn/winter season, which may be explained by the smaller amount of food available and/or the lower level of feeding activity during this time of year. The exception was carp, which had a higher share of fillet in this season, with a significantly lower share of fins. These observations confirm results obtained by Geri et al. [10], who showed that carp living in water at a higher temperature (by 10°C) contained a slightly lower proportion of fillet and a significantly higher proportion of fins. These individuals also had a higher body weight, weight of individual parts, linear dimensions, percentage of remains after filleting, and lower share of skin. However, carp living in water at a higher temperature provided on average 20 g more fillet than individuals from water at a lower temperature, which having a lower proportion of fins and filleting remains, supplied less fish waste.

Table 1
Biometric measurements (cm) and Fulton's condition factor of fish in relation to the fishing season

Specification	Carp		Rainbow trout		Pike		Grass carp		Tench	
	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter
W (g)	$1022.4^{a} \pm 199.18$	$1182.5^{b} \pm 258.05$	$409.8^{a} \pm 83.76$	$469.8^{b} \pm 101.65$	$1196.4^{B} \pm 268.03$	$842.4^{A} \pm 311.56$	1243.1 ± 586.44	1199.8 ± 322.90	476.1 ± 88.80	435.9 ± 175.79
Tl	39.7 ± 3.54	40.6 ± 2.94	34.1 ± 2.99	35.1 ± 2.55	$56.3^{b} \pm 2.87$	$51.9^{a} \pm 6.22$	46.5 ± 6.86	48.2 ± 3.60	32.7 ± 2.47	32.4 ± 4.12
H	$12.3^{A} \pm 0.77$	$13.2^{B} \pm 1.12$	$6.9^{A} \pm 0.45$	$7.6^{B} \pm 0.71$	8.1 ± 1.18	7.5 ± 1.09	9.6 ± 1.61	9.2 ± 1.02	7.8 ± 0.45	7.4 ± 0.87
h	4.6 ± 0.50	4.8 ± 0.40	2.9 ± 0.27	2.9 ± 0.26	3.1 ± 0.21	2.9 ± 0.46	4.3 ± 0.79	4.5 ± 0.32	3.9 ± 0.27	3.7 ± 0.53
lh	9.7 ± 2.29	9.5 ± 0.85	6.5 ± 0.63	6.8 ± 0.71	$14.9^{b} \pm 0.92$	$13.4^{a} \pm 2.27$	8.7 ± 1.15	9.0 ± 0.65	6.6 ± 0.39	6.0 ± 1.48
hh	6.2 ± 0.67	6.5 ± 1.11	$3.6^{A} \pm 0.33$	$4.2^{B} \pm 0.40$	$5.4^{b} \pm 0.42$	$4.8^{a} \pm 0.46$	5.5 ± 0.90	5.5 ± 0.33	4.3 ± 0.37	4.3 ± 0.55
F	1.6 ± 0.24	1.8 ± 0.23	1.0 ± 0.14	1.1 ± 0.14	$0.7^{B} \pm 0.05$	$0.6^{A} \pm 0.07$	$1.2^{B} \pm 0.10$	$1.0^{A} \pm 0.07$	$1.3^{b} \pm 0.13$	$1.2^{a} \pm 0.10$

W – body weight, Tl – total length, H – greatest body height, h – smallest body height, lh – head length, hh – head height, F – Fulton's condition factor ($F = (W \times 100) \times Tl^{-3}$)
Means in rows marked with different letters differ significantly: a, b at $P \leq 0.05$; A, B at $P \leq 0.01$

Table 2
Percentage share (%) of individual body parts in the carcass weight of fish in relation to the fishing season

Specification	Carp		Rainbow trout		Pike		Grass carp		Tench	
	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter
Viscera	11.94 ±2.55	12.14 ±3.02	9.51^{A} ±2.13	11.80^{B} ±2.93	10.38 ±3.21	12.02 ±6.11	12.72^{B} ±2.26	9.98^{A} ±2.51	7.99 ±2.99	6.90 ±2.00
Fins	5.06^{B} ±0.68	3.93^{A} ±0.87	4.41^{B} ±0.63	3.02^{A} ±0.65	3.96 ±0.39	3.54 ±0.62	3.13 ±0.79	2.88 ±0.39	6.25 ±1.82	6.68 ±2.24
Bones	13.99 ±1.99	13.88 ±1.18	11.33 ±1.79	11.01 ±1.40	8.99 ±0.93	8.87 ±1.23	12.01 ±1.40	13.40 ±1.72	14.30 ±1.62	15.49 ±1.43
Skin	9.44 ±1.38	8.58 ±1.21	8.87 ±1.69	9.09 ±1.14	9.28 ±0.91	10.41 ±2.00	11.27 ±1.20	11.63 ±1.83	14.89 ±1.41	14.13 ±1.58
Fillet	40.46 ±1.60	42.24 ±1.49	54.64 ±2.15	53.52 ±1.45	55.78 ±1.33	51.6 ±3.84	52.94 ±0.92	51.12 ±2.02	48.88 ±1.17	45.12 ±1.85

Means in rows marked with different letters differ significantly: A, B at $P \leq 0.01$

The harvesting season significantly influenced the physicochemical parameters of the muscle tissue of the fish species (Table 3). In the autumn/winter period, the pH of the muscle tissue was significantly lower ($P \leq 0.05$) in the rainbow trout and significantly higher ($P \leq 0.01$) in the tench, as compared to the tissue of these species obtained in the spring/summer season. Significant differences ($P \leq 0.01$) between seasons were also found in the case of electrical conductivity (EC): in the spring/summer period the muscle tissue of pike and tench showed a higher EC, while rainbow trout showed a lower EC, compared to individuals of these species from the autumn/winter. The harvesting season significantly influenced the water-holding capacity of the muscle tissue of grass carp ($P \leq 0.05$) and tench ($P \leq 0.01$): this parameter (expressed by the M/T ratio) was lower in these species in the autumn/winter season.

The season did not determine the lightness (L*) of the fillets of the fish species (Table 3). However, significant differences were found for chromatic parameters a* and b*. The pike fillet obtained in the spring/summer season had significantly less ($P \leq 0.01$) red compared to autumn/winter period. The b* parameter in the spring/summer season was also significantly higher ($P \leq 0.05$) than in the autumn/winter in the rainbow trout fillet and significantly lower ($P \leq 0.01$) in the carp fillet. In the latter species the values were negative, which indicates a change in colour from yellow to blue.

There are few papers in the available literature on the impact of the season on the physicochemical parameters of fish meat. In the course of several years of research on commercially caught cod, Love [19] showed that in most individuals of this species the post-mortem pH was above 6.7 for most of the year, with a sudden but short-term decline in the summer (May–August). Lavety et al. [16], in a study on farmed salmon, also noted a decrease in post-mortem pH in the summer (June–July), accompanied by the phenomenon of gaping, i.e. holes and slits in the fillet. In contrast, no significant differences in this parameter between seasons were found by Litwińczuk et al. [18] in silver carp or by Skałecki et al. [24] in perch. The pH obtained in the present study was independent of the season, and was higher than the threshold value of $pH_{24} = 6.5$ given for fresh fish meat by Marx et al. [20].

Litwińczuk et al. [18] found that the harvesting season of crucian carp affected the electrical conductivity of the meat. The muscle tissue of fish caught in autumn had a significantly lower EC (1.8 mS cm^{-1}) than that of individuals caught in spring (4.0 mS cm^{-1}). Skałecki et al. [24] report that the harvesting season did not affect the EC of the muscle tissue of wild perch. In addition, that paper showed no effect of this factor on meat lightness or the share of yellow, and significant differences were found only in the case of red colour; individuals harvested in spring had a higher share of red (6.98) than fish caught in autumn (5.48).

The harvesting season significantly determined the total weight of carp, rainbow trout and pike, as well as the value of some biometric parameters, i.e. the maximum body height in carp and rainbow trout and the total length and head length in pike. Pike, grass carp and tench had significantly poorer body condition in the autumn/winter than in

Table 3
Physicochemical parameters of fish muscle tissue at 24 h *post mortem* in relation to the fishing season

Specification	Carp		Rainbow trout		Pike		Grass carp		Tench	
	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter	spring/ summer	autumn/ winter
pH	7.02 ±0.46	6.82 ±0.36	6.71^{b} ±0.16	6.60^{a} ±0.17	6.60 ±0.49	6.79 ±0.36	6.82 ±0.46	6.78 ±0.41	6.64^{A} ±0.30	7.06^{B} ±0.33
EC (mS cm^{-1})	1.6 ±0.44	1.4 ±0.45	4.0^{A} ±1.34	5.2^{B} ±1.16	2.7^{B} ±0.65	1.6^{A}±0.38	1.7 ±0.66	1.8 ±0.49	2.2^{B} ±0.40	1.4^{A} ±0.15
M/T (%)	48.07 ±12.97	39.86 ±8.14	55.52 ±11.85	59.65 ±6.60	38.57 ±6.33	48.68 ±24.73	45.26^{b} ±8.56	35.97^{a} ±7.39	35.20^{B} ±7.45	23.88^{A} ±6.98
L*	51.16 ±2.46	53.02 ±3.90	52.18 ±5.15	53.21 ±2.68	53.80 ±1.78	53.45 ±3.41	52.23 ±2.47	51.90 ±2.62	51.62 ±2.36	53.43 ±3.10
a*	14.49 ±1.92	14.86 ±2.34	13.78 ±3.51	14.71 ±2.37	8.40^{A} ±1.40	10.78^{B} ±1.58	11.85 ±1.34	11.03 ±2.17	11.19 ±1.66	9.99 ±1.18
b*	$–0.82^{A}$ ±0.98	2.27^{B} ±1.95	6.10^{b} ±4.03	3.68^{a} ±2.17	2.87 ±0.70	2.51 ±1.06	0.00 ±0.98	–0.97 ±0.79	–1.36 ±0.44	–1.50 ±1.13

EC – electrical conductivity, M/T ratio – meat area/total area × 100, L*– lightness, a* – red, b* – yellow
Means in rows marked with different letters differ significantly: a, b at $P \leq 0.05$; A, B at $P \leq 0.01$

the spring/summer. The season significantly influenced the share of viscera in rainbow trout and grass carp and that of fins in carp and rainbow trout, but the share of valuable edible parts (fillet) did not differ significantly between seasons. The season was shown to significantly affect the physicochemical parameters of the muscle tissue: pH in rainbow trout and tench, electrical conductivity in trout, pike and tench, and the M/T ratio in grass carp and tench. The season did not significantly influence the lightness (L*) of the fillets of the fish species. Significant differences were noted for chromatic parameters a* (pike) and b* (carp and rainbow trout). In common carp, the b* parameter was negative in the spring/summer season, which indicates a change in colour from yellow to blue. Despite the differences noted, no clear and consistent effect of the harvesting season on total weight, biometric parameters or proportions of body parts was found in the fish species. The harvesting season also had no clear effect on the physicochemical parameters of the muscle tissue of the fish tested.

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