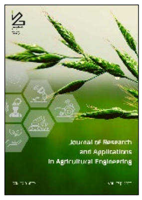
Article citation info:
Mierzejewska S., Skarbek E., Bać A., Domiszewski Z., Piepórka-Stepuk J., Dowgiałło A., Diakun J., 2024. The Effect of Preliminary Processing of African Catfish on Mass Yield of Major Product Forms Compared with Carp. *Journal of Research and Applications in Agricultural Engineering* 69 (2): 5-12. https://doi.org/10.53502/YIDA5187

Łukasiewicz Poznań Institute of Technology

Journal of Research and Applications in Agricultural Engineering

Journal website: https://tech-rol.eu/



The Effect of Preliminary Processing of African Catfish on Mass Yield of Major Product Forms Compared with Carp

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Article info
Received: 20 October 2023
Accepted: 13 June 2024
Published: 15 October 2024

Keywords
African catfish
carp
culinary elements of fish
carcass

The article compares the morphological structure of the skeletal and muscular systems of carp and catfish carcasses and discusses how this affects the mass yield of pre-processed culinary products. The results of weight measurements of the elements obtained from the processing of catfish carcasses, such as gutted carcasses, headless carcasses, flaps, and trimmed fillets without skin, are presented. The processing and measurements were carried out on 34 fish (total weight 45 kg). The weight of individual fish in the study group ranged from 630 g to 2160 g. Measurements were rec-orded separately for three size categories of fish.

DOI: 10.53502/YIDA5187

1. Introduction

In Polish freshwater aquaculture production, the leading position is taken by carp (10–20 thousand tons per year), in second position is trout, and in third position, with an upward trend in its share of total production, is African catfish. At the beginning of 1990, African catfish production was about 60 tons per year, while according to FEAP data for 2019, it was about 800 tons. In commercial supply, processing and catering, carp is essentially well established. In terms of demand it is mainly considered a seasonal and holiday product. Carp farming is also seasonal, taking advantage of the warmer seasons and the favorable late autumn sales for farmers. In the case of African catfish, a significant difference from carp is that its breeding is not seasonal, but continuous [1]. Another advantageous aspect of African catfish farming is the possibility of managing hot water, which, when directly discharged into the environment, is a waste substance that must be paid for [2].

Poland consumes an average of 14 kg of fish (compared with 64 kg of meat) per person per year [3]. This is only about 50% of the figure for other European countries, and puts Poland a long distance behind some countries, such as Sweden (26.9 kg), Italy (28.4 kg), France (33.9 kg), and the leading country, Portugal, with an annual consumption of 55.9 kg/person [4]. This pattern is explained by the local availability of raw fish, traditions, and gastronomic culture. Fish meat, compared with pork meat, which is common in Poland, is characterized by a fatty acid composition that is beneficial to health [3, 5]. In the context of health improvement, all kinds of activities promoting and supporting increased consumption of fish are expedient.

Meat from carp (5–8%) and African catfish (3.5–6%) are assigned to the semi-fatty group, with favorable lipid composition [6]. Fish lipids, due to their biological properties, are known for the ability to prevent many diseases, including circulatory system diseases, cancer (liver, breast), and the so-called neurodegenerative diseases (dementia, Alzheimer's disease, and depression) [7]. The meat of African catfish has an attractive texture comparable to veal, and does not have an intense fishy smell. A factor that might improve the low level of consumption would be increased availability of pre-processed products that are easy to prepare for consumption: gutted carcasses, flaps, fillets. In retail sales and in sales to the catering industry, the attractiveness of offered products is improved by appropriate pre-treatment (boneless, incised flaps) and packaging in a modified atmosphere to prolong shelf life.

2. Aim and Scope of the Study

The breeding of African catfish and carp, due to its compatibility with sustainable development, plays an increasingly important role in combating malnutrition and even hunger, especially in African and Asian countries. There is a lack of scientific studies on the mass yields of individual culinary elements as percentages of the weight of the African catfish carcass. For this reason, it is reasonable to develop optimal techniques for obtaining such elements for the catering and fish industries.

The article characterizes culinary elements for catering and for retail sale from African catfish, comparing the findings with those from extensive studies of carp. Analyses indicate which elements produced from the carcass of carp and African catfish are attractive for catering and retail, as forms convenient for culinary preparation. In studies such as Professor A. Dowgiallo's monograph [8] and guidebooks on carp [9, 10], information on carp products and mass ratios of individual elements is presented at great length. This paper presents a comparison of the culinary elements of catfish and carp, as well as the percentage mass yields of the elements produced by technological processing of African catfish.

3. Research Methodology

3.1. Mass Yield of Culinary Elements from Catfish

The operations of cutting catfish carcasses into pieces and measuring their weight were carried out for 34 fish with a total weight of about 45 kg. They were obtained from a natural catch from a farmer. The minimum carcass weight was 0.63 kg, and the maximum was 2.16 kg. The fish were divided into three weight categories (A–C), shown in the first column of Table 1, where the second column indicates the quantities of fish in each group. The rows contain the results of measurements and calculations of the percentage yield of products for each size group, and the last row shows the average values for the entire fish mass studied. African catfish cannot be decapitated using the standard methods applied with flat-sided fish such as carp [11]. In this study, a decapitation cut was made from above, directly behind the skull bone. Measurements were made of the weight of the following elements resulting from catfish carcass processing: carcass after gutting with the head (Tpzg), carcass after gutting and cutting off the head (Tpbg), flaps after cutting them off from the backbone and cutting off the ventral fins (P), as shown in Fig. 4b, and the fillet obtained after cutting off the ventral zone, aligning the periphery (trimming) and skinning (Ft), as shown in Figure 7. The statistical scatter of the measurements was calculated and tabulated in the form of standard deviation values.

3.2. Statistical Analysis

The numbers presented in the tables and figures are mean values. Statistical analysis was based on two-way analysis of variance; homogeneous groups were formed according to Tukey's test for $P \leq 0.05$. The data were statistically analyzed using the data analysis software system Statistica (2005 version) by StatSoft Inc.

4. Fish Morphology

Whole carcasses of carp and African catfish for processing and retail have weights in the range 0.8–1.8 kg and lengths from 47 to 58 cm. Figure 1 shows carp and catfish and their characteristic cross-sections. The photographs show fish with an approximate weight of 1.5 kg. The natural positioning of the carp carcass on the table for its processing is a sideways positioning, while that of catfish is a ventral positioning.

Fig. 1. Catfish and carp in suitable positions for culinary processing, and cross-sections of fish carcasses through the abdominal and caudal zones for (a) catfish and (b) carp

Carp and African catfish have significantly different arrangements of carcass morphology. This determines what elements can be obtained for culinary processing. Figure 1 shows views of the fish and characteristic cross-sections of carp and catfish gutted carcasses through the abdominal and caudal chambers. The different dimensional proportions of the carcasses are highlighted. Our own research shows that the catfish, with comparable weight, is longer than carp. The cross-section of carp is narrower, and the arrangement of ribs determines the nature of the cross-section and the form of the flap that will be obtained from a flap cut (flaps are elements without backbone, but with rib bones and skin). The cross-section of the carcass of catfish shows a significantly larger cross-sectional thickness over the backbone zone, compared with carp. The arrangement of ribs in the cross-section of catfish is different. There are short, rigid rib processes and their extension is the thin, flexible rib bones of the abdominal zone. In the rib (abdominal) zone of catfish, the carcass thickness is small.

The simplest form in which aquaculture fish are sold on the retail market is whole carcasses. However, this form has the shortest shelf life. Whole fish cannot be offered in packaging that extends shelf life using, for example, polymer film packaging and gas mixtures (modified atmosphere). Individual consumers and caterers buying whole fish have a high degree of certainty that they are receiving a fresh product. Whole fish carcasses are offered by breeders or retail establishments that can provide appropriate conditions for sale through logistics ensuring the sustainability and quality of the raw material.

In preparation for culinary processing, the first step is evisceration. This operation produces solid waste in the form of guts. In the case of preparation of dishes from a small unit quantity of fish, a small amount of waste is generated in the gutting operation and its management is not a problem, although it is often not properly disposed of. However, the processing of a large quantity of fish, in the case of industrial (bulk) processing, generates a need for controlled waste management. Farmers selling whole fish avoid the problem of waste disposal, but lose the additional revenue resulting from the higher price of processed products. In large-scale processing, waste must be identified and professionally disposed of. Some waste from fish gutting can be used as by-products or co-products. It is reasonable that, for the sake of full management of carcass parts, the minimization of waste and professional waste disposal, fish should undergo preliminary processing under industrial conditions. At a small scale, this can be carried out by breeders or small plants cooperating with breeders. Carcass with head is the simplest processed form. This form is attractive in catering if the culinary technology uses carcass parts such as head, fins and backbone to prepare stock for soups or jellies. Individual customers and catering establishments can make a variety of dishes using the carcass.

After gutted fish, a higher level of processing results in gutted, deheaded carcasses with the side fins cut off. Through industrial deheading, a pre-processed fish product with a higher degree of "purity" is offered, but at the same time in industrial conditions there is a need to manage the disposal of heads and fins. A gutted, deheaded carcass can be offered in packaging with a modified atmosphere, which prolongs its shelf life. Deheading performed manually is a time-consuming and costly operation. In one research project [12], a carp deheading machine (with a favorable peri-bronchial cut) was designed and manufactured for small fish processing plants (Fig. 2). Another study analyzed the conditions for mechanical deheading of catfish, resulting from the morphology of the fish carcass [11].

The morphologies of fish carcasses determine the types and major forms of products obtained. In the case of carp, the deheaded carcass can be cut into "darnes" – sliced whole fish after deheading and evisceration (Fig. 3). Darne-cutting can be done manually as part of culinary (kitchen) processing, or by machine in the preparation of a convenient product for retail sale and for catering.

This product can be offered for sale in modified atmosphere packaging. An advantage of machine cutting over manual cutting is that it produces uniform shaped pieces. Fig. 3 shows a darne-cutting machine designed for small capacity operations (small fish processing enterprises or catering establishments), designed and manufactured as part of a research project [13]. Due to the form of the cross-section, catfish carcasses are not cut into darnes.

Elements convenient for gastronomic processing include flaps (elements without backbone, but with rib bones and skin). Darnes and flaps contain the maximum amount of meat from the carcass for gastronomic use. Cross-sectional views of carcasses of carp and catfish (as shown in Figure 1) highlight the possible forms of flaps. The forms of the flaps are conditioned by the arrangement of the ribs and the thickness of the muscles in the dorsal and ventral zones.

Carp and catfish flaps, along with the excised spines, are shown in Figure 4. It can be seen that the shape of the carp flap is determined by the rib bones. It has even muscle thickness in the dorsal and ventral zones. It provides a shapely, cohesive piece for culinary use. The catfish flap has two distinct zones: a dorsal zone of high thickness and a ventral zone of low thickness (fleshiness). The catfish flap, due to the form of the abdominal zone, is not attractive as a single overall culinary element.

Fig. 2. Deheader for carp with a circular cut (prototype)

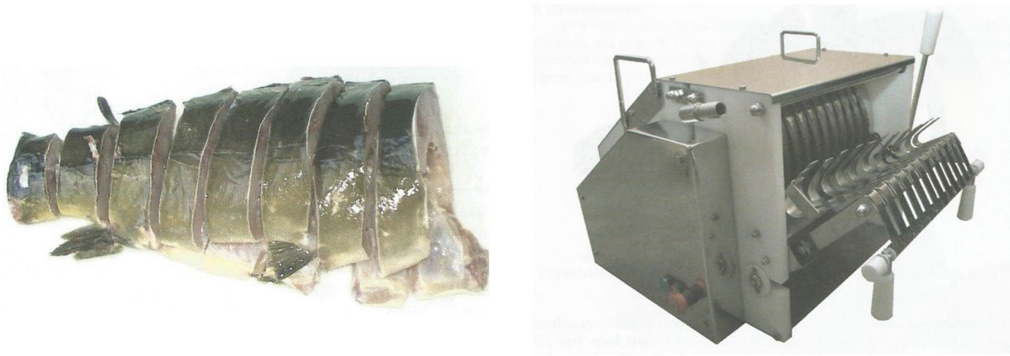

Fig. 3. Carcass of carp cut into darnes, and a machine (prototype) for darne-cutting

When flaps are trimmed in a catering plant or kitchen, the backbone with the meat remaining on it is a co-product that can be used for stock for fish soups, but is also very often a waste product. In industrial processing, it is profitable to recover meat from backbones manually using a scrape-spoon in the case of salmon, or by pressing it on mechanical separators, mainly in the case of white-meat fish. Meat recovered in this way accounts for 50% to 68% of the weight of the punched backbones (backbones make up about 17% of the weight of the fish), and thus the recoverable meat amounts to about 10% of the weight of the fish [8, 9, 10].

The most "refined" form of culinary product resulting from carcass processing is fillets (flaps without ribs). They can be produced with or without skin. In the case of carp, the skin is thin and delicate, and it is even advisable that it remain on the fillet because it increases its cohesiveness. Problematic elements in carp carcasses include the intramuscular bones. They are essentially impossible to remove from the flap or fillet, and pose a danger of choking during consumption.

It is possible to neutralize them by incising the fillet at intervals of 3 to 4 mm, as shown in Figure 5. This operation makes the intramuscular bones imperceptible during consumption. As part of a previous project [12], a table-top fillet bone cutter (shown in Figure 5) was designed and manufactured.

Catfish fillet is obtained by trimming off the abdominal zone, where the ribs occur, and then trimming to even out and smooth the form of the resulting fillet. A view of a trimmed flap used to form a trimmed fillet is shown in Figure 6. Research shows that catfish fillets have greater thickness (fleshiness) than carp fillets. After trimming, fragments from the flap remain, which are small but valuable meat trimmings. These can be used culinarily in minced meat products such as meatballs and sausages. The skin of catfish is significantly thicker and noticeable in texture during consumption. To improve the attractiveness of the fillet, de-skinning is expedient. The significant thickness (fleshiness) of the catfish fillet does not result in a loss of cohesiveness of the element, as occurs in case of de-skinning of carp fillets. The most processed form – trimmed without skin, "refined" –is referred to as a loin.

Fig. 4. Flaps and severed spines for (a) carp and (b) catfish

Fig. 5. Cut carp fillet and bone cutter (prototype) for carp fillets

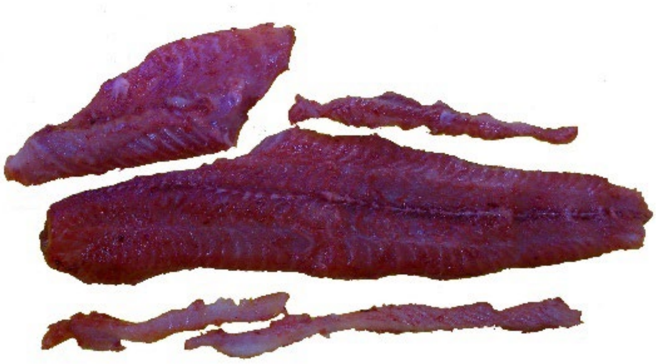

Fig. 6. Catfish fillet with elements trimmed from the flap in the process of obtaining a trimmed fillet

4. Results and Discussion

The results of our measurements of the mass yields of individual elements extracted from the carcass of African catfish are given in Table 1 and presented in graphs in Figures 7 and 8. The equivalent figures for carp carcasses are presented in reference studies [9,10].

The first graph shows the percentage yields of individual elements in the three groups of fish by mass, and for the entire quantity studied. The weight of the elements is seen to decrease with the creation of culinary elements with a higher degree of processing (more refined elements). Figure 8 shows the same percentage values grouped by type of element, revealing differences in the shares represented by a particular element between weight groups.

This graph shows that the highest mass yield of culinary elements is obtained in group A. The largest difference, of more than 6% (statistically significant), between the groups of small and large fish is found the case of fish after gutting (carcass with head, Tpzg). For elements with a higher degree of processing (refinement), the differences are already insignificant. When deciding what mass of fish should be harvested and processed, the weight of the elements may also be important. For large fish (about 1.8 kg), a single trimmed fillet without skin (loin) has a weight of about 280 g, while for small fish (about 0.8 kg) it has a weight of about 120 g. Pieces of larger weight are more attractive; they can be divided into smaller pieces in culinary processing.

The averaged mass yields of individual elements obtained from catfish carcasses are as follows: gutted carcass with head – 86.5%, carcass without head – 61.4%, flaps – 48.5%, trimmed fillet without skin (loin) – 31.6%. The dispersion in values is largely due to differences between females and males (differentiation of roe and milt weight) [14]. For comparison, the mass yields for carp are as follows: gutted carcass with head – about 86%, gutted carcass without head – about 63%, flaps – about 56%, fillet with skin – 42.0% [6, 8]. The difference in mass ratios after heading is significant. The head accounts for a larger percentage of the weight of the carcass in catfish (25%) than in carp, especially in the case of precise deheading with a peri-bronchial (round) cut (23%); this can be achieved using a deheading machine (Figure 2) which allows precise setting of the cut line with a laser pointer.

Table 1. Mass of whole catfish in groups A–C and yields (%) of products of preliminary processing

Group and mass range [g]	No. of fish [pcs]	Mass of whole fish [g]	Gutted carcass with head (Tpzg)	Gutted carcass without head (Tpbg)	Flap (P)	Trimmed fillet without skin (Ft)
A: 600–999	11	804.4^{a} ±105.3	89.8^{b} ±5.7	62.2^{a} ±4.8	48.0^{a} ±4.6	30.6^{a} ±3.3
B: 1000–1499	14	1085.1^{b} ±113.9	86.5^{ab} ±6.1	62.2^{a} ±3.8	48.6^{a} ±2.6	32.3^{a} ±2.4
C: > 1500	9	1797.8^{d} ±231.1	83.1^{a} ±4.4	59.0^{a} ±3.5	47.4^{a} ±2.9	30.4^{a} ±2.3
total	34	1287.7^{c} ±414.0	86.5^{ab} ±5.9	61.4^{a} ±4.2	48.5^{a} ±3.4	31.2^{a} ±2.6

a, b, c: values followed by the same letters in a column (for the same parameter) are not significantly different from each other at the level P ≤ 0:05.

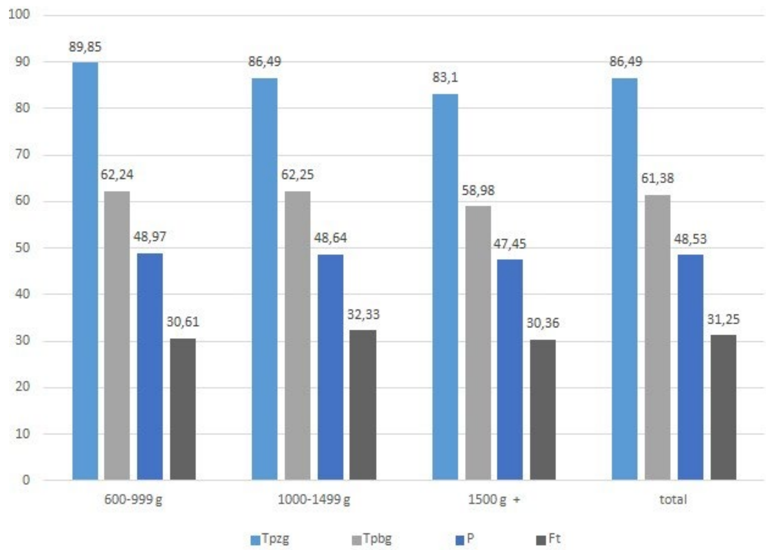

Fig. 7. Percentages of individual elements within the three analyzed weight groups: **Tpzg** – gutted carcass with head, **Tpbg** – gutted carcass without head, **P** – flap, **Ft** – trimmed fillet without skin

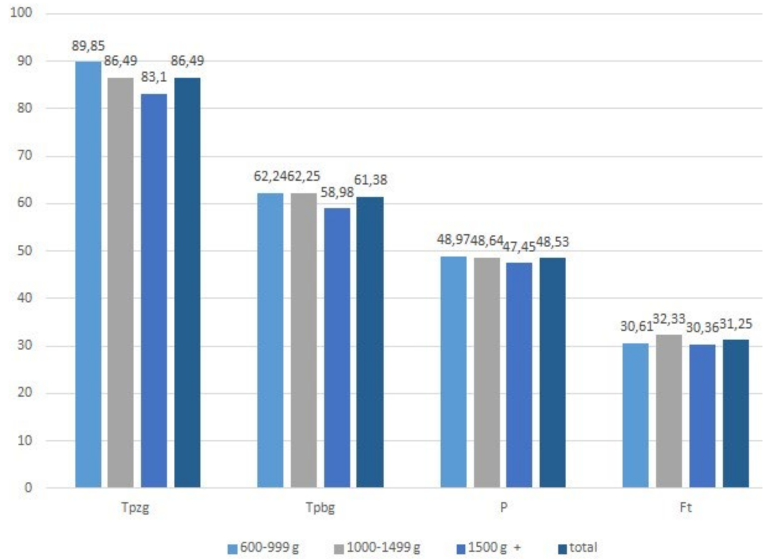

Fig. 8. Mass ratios of elements formed from catfish carcasses: **Tpzg** – gutted carcass with head, **Tpbg** – gutted carcass without head, **P** – flap, **Ft** – trimmed fillet without skin

5. Summary

Carp and African catfish belong to the category of semi-fatty fish. They are obtained from farming (aquaculture). They offer similar possibilities for obtaining elements from the carcass for culinary use. Differences are due to the morphology of the musculoskeletal system.

Elements supplied to the catering industry and for retail following the preliminary processing of carp and catfish carcasses include gutted carcasses, headless carcasses, flaps, and fillets. These elements can be packaged with a modified atmosphere to extend their shelf life.

Due to the morphology of the carcass, elements specific to carp include darnes and fillets with cuts that reduce the perceptibility of the intramuscular bones during consumption. For catfish, a specific culinary element may be a trimmed fillet, without skin.

From the measurements carried out for a total of 34 fish with unit weights ranging from 0.63 to 2.16 kg, the following mass yields were obtained for particular elements: gutted carcass – 86.5%, headless carcass – 61.4%, flaps – 48.5%, trimmed fillet without skin (loin) – 31.6%. Significant differences (of around 6%) in mass yields depending on the size of the fish were found only for gutted fish.

The manufacture of a range of pre-processed carp and catfish products, convenient for catering, carried out in small-scale industrial conditions, can make their supply more attractive, enables the management of by-products and waste, and can increase demand for these fish, which is beneficial for nutritional and health reasons.

Carp is a fish with well-recognized morphology in terms of gastronomic elements. The catfish is less well-known in this respect and further research is recommended. The morphometric parameters of African catfish differ from those of carp.

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