Guidelines and Implications of Fish Slaughtering in the Ensuring of Welfare and Product Quality

Anca BOARU, Dănuţ STRUÞI, Bogdan GEORGESCU*

Faculty of Animal Science and Biotechnologies, University of Agricultural Sciences and Veterinary Medicine, Mănăștur Street No. 3-5, Cluj-Napoca, code 400372, România

* Corresponding author: B. Georgescu e-mail: georgescu.bogdan63@yahoo.com

REVIEW

Abstract

The constant and accelerated increase of world fish production through the expansion of fisheries and the development of aquaculture has also generated a higher interest in animal welfare. In the present, is proven that the fish welfare is a factor that influences the quality of the product and the practices of capture and slaughter, which can compromise these attributes. The harvesting and suppressing life methods give to the biochemical processes of fish meat some particularities, as a result of the stressor to which it is subjected by tracking, agglomeration, space restriction and asphyxiation. In the view of all, it is important to correctly identify procedures that improve both the welfare of the fish and the quality of the product. In this review, there are highlighted some of the stunning and slaughter methods of fish used in the aquaculture or capture fisheries, focusing on the human agreed standards and international organizations. There are recommendations in this sense for operations prior to slaughter and the possibility of developing and implementing new methods, by country and species of fish. In this sense, the brain puncture stands out as a more humane method of slaughtering fish, which also improves the quality of the product.

Keywords: Fish; harvesting; ike-jime; stressor; welfare.

INTRODUCTION

The ichthyofauna of the seas, oceans and inland waters has a particular importance for the world’s fish economy (FAO, 2016). On the other hand, the fish farming production is very close to that of the catch fishery and it is estimated that by 2030, more than 60% of the total fish intended for human consumption will come from aquaculture (World Bank, 2013; Cooke, 2016). Globally, fisheries and aquaculture contribute to human food products by providing a significant amount of animal protein (FAO, 2020). With the expansion of offshing and the development of aquaculture, interest in fish welfare has also increased (Poli et al., 2005; Poli, 2009) both for ethical reasons and from the perspective of improving standards and quality of production technologies and aquaculture products (Segner et al., 2019). Catching, handling and transport are traumatic procedures (Borderías and Sánchez-Alonso, 2011) that can influence the fish welfare (Metaxa, 2003; Yue, 2008) and slaughter techniques have a significant effect on the meat quality (Poli et al., 2005). After capture and slaughter, a series of biochemical processes take place in the body of fish and their management can significantly influence the quality, preservation and shelf life of the product (Poli, 2009). The basic principles of slaughter are similar for all animal species (FAWC, 1996) and refer to the rapid loss of consciousness without causing pain followed by death assessed by the loss of brain function without regaining consciousness (Ashley, 2007; Davie and Kopf, 2006; Southgate and Wall, 2001). The methods used to slaughter fish most often
do not reduce stress and there is a growing awareness today of performing slaughter in humane conditions using first a stunning method that causes immediate loss of consciousness (EFSA, 2004, 2009). This review discusses the general issues and aspects of the practice of stunning and killing fish, focusing on welfare and quality, in accordance with international standards.

THE BIOCHEMICAL PROCESSES THAT TAKE PLACE AFTER CATCHING FISH

After being slaughtered, the fish go through the stages of rigor mortis, the disappearance of rigor mortis, autolysis and bacterial damage (Sigholt et al., 1997). The methods of harvesting and suppressing life imprint certain characteristics on the biochemical processes in fish meat that can also have an effect on meat quality (Iurca, 2006; Le et al., 2020). Stress during harvesting and before death influences post-mortem biochemical processes, such as the rate of degradation of adenosine triphosphate (ATP), the onset of rigor mortis, and the appearance of decomposition processes (Poli, 2009). Overcrowding, capture and handling procedures are traumatic, the body reacts by activating the sympathetic-adrenergic system and cause significant physiological reactions (Iwama et al., 2006; Wedemeier et al., 1990). Fish under stress try to find adaptation mechanisms that cause some changes biochemical, physiological and behavioural order (Munteanu and Bogatu, 2003). This General Adaptation Syndrome (Selye, 1950) causes the release of adrenaline and cortisol followed by secondary changes such as increased muscle activity, mobilisation of energy stores in muscle and liver and changes in acid-base balance (Sigholt et al., 1997). The prevention and management of these processes that take place in the body immediately after capture by various techniques can maintain the quality and freshness of fish (Harada, 1988).

METHODS OF STUNNING AND SLAUGHTERING FISH

Asphyxiation

Asphyxiation is a common method of slaughter used by sport fishermen but also by fish farmers (Davie and Kopf, 2006; Diggles and Landos, 2012). Fish metabolic rate is dependent on temperature, oxygen requirements are being reduced when the ambient temperature decreases, and asphyxia generally occurs when the air and water temperature is reduced (Poli et al., 2005; Southgate and Wall, 2001). Asphyxiation can be done by removing the fish from the water or by storing them in a container with water that is not aerated (Diggles and Landos, 2012). In both cases, fish fight violently and try to escape (Robb and Kestin, 2002), the method is extremely stressful and results in physiological and biochemical changes that significantly reduce the quality and the duration of freshness of the product (Harada, 1988). Even though it is easy and cost-free it is not considered a humane method of slaughtering fish (Lines and Spence, 2014). By keeping fish in water that is not aerated or in degassed water, death occurs due to asphyxiation because of the lack of dissolved oxygen, but also because of the accumulation of excretion products that become toxic to the body; the fish have violent and rapid reactions (Erikson et al., 2006; Robb and Kestin, 2002). It has been shown that the time until fish die in the air depends on the species and the ambient temperature. The rainbow trout (Oncorhynchus mykiss) dies after 2.5 minutes at 20° C, after 3 minutes at 14° C and after 9.6 minutes at 2°C. In Atlantic salmon (Salmo salar) brain death occurs after 2-3 minutes at 20°C but at 2°C only after about 14 minutes. The eel (Anguilla spp.) can survive more than 24 hours out of the water if there is moisture and wild carp (Cyprinus carpio) is also very tolerant to hypoxia (Diggles and Landos, 2012; Hastein et al., 2005; Poli et al., 2005).

Carbon dioxide saturation

Reducing the sensitivity and activity of fish can be done by replacing oxygen (O2) with carbon dioxide (CO2) and is a common method practiced in aquaculture (Yue, 2008). By saturating the water with CO2, an acidic environment with O2 deficiency is created, which induces a state of narcosis in the fish (SANTE/2016/G2/009). As a response to stunning with CO2, fish have strong reactions, try to escape, the scales come off and the secretion of mucus increases (Robb and Kestin, 2002). Although these manifestations of fish do not recommend it as a humane method of stunning before slaughter (Waley et al., 2021), some results show that better stress response performance can be achieved if CO2 is used compared to asphyxiation of fish in ice. In the European perch (Dicentrarchus labrax) for example, the onset of death was 16 minutes after the fish were exposed to CO2 and 34 minutes after hypothermia (Acerete et al., 2009).

Hypothermia

By placing the fish in cold water or ice slurry, thermal shock, numbness and eventually death by asphyxiation are induced (EFSA, 2009; Yue, 2008). The metabolic rate of the fish is temperature dependent and the oxygen requirement is lower in cold water; thus, it results that the asphyxiation occurs later and the process is delayed as the water temperature is lower (Robb and Kestin 2002; Southgate and Wall, 2001). If the fish are placed in an ice suspension, the body temperature decreases depending on the initial temperature of the fish but also according to
their body weight (Morzel et al., 2002). For small fish and for those that come from or are adapted to temperate tropical and warm areas, the thermal shock can shorten the time interval to a few seconds until the loss of brain function and death appears (Diggles and Landos, 2012; Diggles, 2016). It was concluded that stunning by lowering the temperature in an ice suspension is effective and environmentally friendly for small fish, when the water temperatures are higher than 20 °C (Stevens and Fry, 1970; Skjervold et al., 2002; Morzel et al.). It is also recommended for the slaughter of commercial species (EFSA, 2009).

**Bleeding**

In the case of which the bleeding of the fish is necessary during the process of handling, they are beheaded or even gutted while they are conscious (Waley et al., 2021). While not considered an ideal method of killing for any animal species, because the brain continues to function for some time, fish (pangasius, tilapia, eel) are beheaded without prior stunning (Lines and Spence, 2014). Bleeding or exsanguination is a necessary step in the processing and recovery stage, which is applied during or after the slaughter of the fish, in order to maximise the quality of the final product (Roth et al., 2007). For this purpose, the gills are cut or extracted manually, respectively the caudal vein is cut (Robb et al., 2000) after which the fish is usually reintroduced into the water (Iurca, 2006). The amount of time in which the fish loses its brain function depends on the species, the method applied, the size of the specimen and the water temperature (SANTE/2016/G2/009). After cutting the gills and without a previous stunning in Atlantic salmon (Salmo salar) brain function is lost after 4-5 minutes (Robb and Kestin, 2002) but in the turbot (Psetta maxima) it was found that bleeding after cutting the gills and putting it in water was a very slow method of slaughter (Morzel et al., 2002). It has been concluded that the method alone is stressful and therefore not an ideal method of killing fish (EFSA, 2004; Yue, 2008). On the other hand, bleeding of the fish after stunning does not affect the quality, which is why most authorities consider that the fish should be exposed to bleeding only after being stunned or killed by other methods, such as stabbing the brain or percussive stunning (Diggles and Landos, 2012).

**Percussive stunning**

The method is considered among the fastest and most humane methods of killing fish (Roth et al., 2007). Using a blunt instrument to induce unconsciousness, requires some amount of skill and is the recommended method for fish caught by anglers (Diggles, 2016). Applying a blow to the head, manually or using a device (Hästein et al., 2005) if performed with sufficient force and precision can result in immediate stunning (Yue, 2008). To be sure that death occurs without recovery, percussive stunning is combined with the bleeding stage. Percussive stunning is not suitable for all species and depends on the catch technique and the environment from which the fish comes from (natural or from the farm). For fish farmed automated devices have been developed that are more accurate. For example, for a more humane killing of wild Alaskan salmon, a method is used that combines percussive stunning by using an automatic machine, followed by manual bleeding (Mood and Brooke, 2019).

**Electrical stunning**

Electrical stunning can be applied either by delimiting a surface of water with electricity, or it can be applied with a device, directly on the fish. The general principle of electrical stunning is to pass an electric current that stimulates the upper nerve centers to cause them malfunctions (Waley et al., 2021). It is a recommended humane method for farmed fish, without being highlighted for catch fish (OIE-Aquatic Animal Health Code, 2019).

**Decapitation or dislocation of the cervical spine**

For some fish (eels), killing methods that separate the head from the body can be used (EFSA, 2004) or the cervical bones are broken, as well as the combination or derivation of these techniques, respectively the sectioning of the spine with a sharp tool (Diggles and Landos, 2012). Depending on the species, loss of consciousness does not always occur immediately upon complete separation of the head from the rest of the body (Waley et al., 2021). The American Veterinary Medical Association (AVMA, 2007) recommends for fish to be decapitated only after percussive stunning is applied first. The recommendation on the application of cervical spine dislocation, decapitation and vertebral sectioning are acceptable methods of killing fish, a statement also made by The Australian and New Zealand Council for the Care of Animals in Research and Teaching (ANZCCART).

**Brain puncture**

Along with percussive stunning, brain puncture is also considered one of the easiest and most humane methods of killing fish, especially those caught by anglers (Davie and Kopf, 2006). Also known as "pithing" or "i'ki jime" (Polli et al., 2005), the method involves inserting a sharp object through the skull of a fish that destroys the brain (Waley
et al., 2021). The fish dies immediately, the stress is greatly reduced, the concentration of lactic acid in the muscles decreases and the contusions or other unwanted changes that occur are also reduced if the fish is allowed to die slowly (in air, water or ice) (Harada, 1988). By minimising the pH drop and a significant delay in the installation of rigor mortis especially if the fish is placed immediately on the ice, the puncture of the brain improves the quality of the meat (https://ikejimefederation.com/press/, https://www.ikejime.com/). It should be borne in mind that it takes a certain degree of experience, skill and knowledge of fish anatomy to accurately puncture the brain which is quite small. In addition, the correct immobilisation of the fish is an important and necessary condition for the application of the method, because the target point could be wrong and the fish suffer (Poli et al., 2005). For these reasons percussive stunning should be applied before the brain puncture. This way it is certain that paralysed fish are easier to catch during the puncture process (Davie and Kopf, 2006). The same recommendation comes from AVMA and ANZCCART who considered that the destruction of the brain trough stabbing is a humane form of euthanasia for fish provided they are paralysed first (https://anzccart.org.nz/; https://olaw.nih.gov/sites/default/files/Euthanasia2007.pdf).

THE REFERENCE STANDARDS

For the evaluation of welfare practices, the leading international organization is The World Organization for Animal Health (OIE) and in the 22nd edition of the Aquatic Code (2019) it provides the standards for the implementation of measures to ensure the welfare of farmed fish, including during transportation, stunning and killing for human consumption or disease control.


The general requirements set out in Council Regulation (EC) No 1099/2009 on the protection of animals at the time of slaughter have contributed to the development of a framework for legislation and standards on the welfare of farmed fish in the EU. The regulation recommends the establishment of specific standards for the protection of fish at the time of slaughter, based on the scientific risk assessment carried out by EFSA, and taking into account the social, economic and administrative implications.

In the report for the European Commission Directorate Health and Food Safety, information on current animal welfare practices in European aquaculture regarding the slaughter of the main farmed fish species was published and analyzed (SANTE / 2016 / G2 / 009). Depending on the country and the fish species, there are a number of stunning and slaughtering methods (Table 1) that are implemented or are being implemented and that more or less meet the standards imposed by OIE and EFSA.

<table>
<thead>
<tr>
<th>Method</th>
<th>The species to which it applies</th>
<th>Benefits</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Electrical stunning</strong></td>
<td><em>Salmo salar</em>&lt;br&gt;<em>Oncorhynchus mykiss</em>&lt;br&gt;<em>Cyprinus carpio</em></td>
<td>It can result in immediate stunning and allows pre-rigidity threading&lt;br&gt;If followed by striking/beheading, the standards are met</td>
<td>It requires an effective method of killing&lt;br&gt;If it is followed by slaughter by cutting the gills, the standards are not met&lt;br&gt;The carcass may be damaged and affect the quality of the product</td>
</tr>
<tr>
<td><strong>Stunning with carbon dioxide</strong></td>
<td><em>Oncorhynchus mykiss</em>&lt;br&gt;<em>Salmo salar</em></td>
<td>Meets the standards&lt;br&gt;It can result in immediate stunning and allows pre-rigidity threading</td>
<td>Stunned may be missed under some conditions&lt;br&gt;Stunned may be missed due to the variable size of the fish&lt;br&gt;It can cause head injury and depreciate the carcass</td>
</tr>
<tr>
<td><strong>Percussion</strong></td>
<td><em>Oncorhynchus mykiss</em>&lt;br&gt;<em>Cyprinus carpio</em></td>
<td>If applied correctly, the fish will not recover&lt;br&gt;Manual hitting can be combined with CO₂ stunning</td>
<td>If applied manually, stunning may be missed&lt;br&gt;If applied manually, the stunning may be missed&lt;br&gt;Head injury can occur</td>
</tr>
<tr>
<td><strong>Live fish refrigeration using carbon dioxide</strong></td>
<td><em>Salmo salar</em>&lt;br&gt;<em>Dicentrarchus labrax</em>&lt;br&gt;<em>Sparus aurata</em>&lt;br&gt;<em>Oncorhynchus mykiss</em></td>
<td>Slow installation of rigor-mortis and allows pre-rigidity threading</td>
<td>The fish are not stunned, and the method is stressful</td>
</tr>
<tr>
<td><strong>Asphyxiation in ice or iced water</strong></td>
<td></td>
<td>It is easy to use in terms of quality and food safety&lt;br&gt;The fish are not stunned, and the method is stressful</td>
<td>It is stressful for fish due to the sudden reduction of the temperature</td>
</tr>
</tbody>
</table>

Table 1. Advantages and disadvantages of methods of stunning and killing fish species in European aquaculture (processing following the Report from the Commission to the European Parliament and the Council, 2018)
To ensure that fish welfare is a priority on the agenda of decision-makers in the European Union (European Parliament, Council and Commission) Eurogroup for Animals also encourages the development of welfare indicators and raising awareness. Through the fish welfare program, they published the report highlighting the risks to which wild fish are exposed throughout the capture and slaughter process, with proposals for measures and strategies to reduce stress and suffering (Waley et al., 2021).

CONCLUSIONS

Fish welfare extends to practices associated with harvesting, stunning, killing, exsanguination and evisceration, to reduce stress and optimize product quality. The development and implementation of humane slaughter methods is a necessary to ensure the well-being in capture fishing and aquaculture. After catching the fish, an effective stunning method must be applied as soon as possible, followed by an appropriate killing method leading to an immediate loss of sensitivity. The World Organization for Animal Health’s welfare recommendations for the slaughter of farmed fish state that the general principle is that fish must be stunned before they are killed, and the stunning method must ensure the immediate and irreversible loss of consciousness. The following mechanical methods are recommended for this purpose: percussive stunning, manual or by using special equipment, brain puncture, iki jime, shooting, for large fish, and electric stunning, in water or on land, for farmed fish.

Author Contributions: A.B. Collected the data; A.B. Contributed to data and analysis tools; G.B. Performed the analysis; D.S., A.B., G.B. Wrote the paper.

Funding Source: The research did not receive any funding.

Acknowledgments

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest

The authors declare that they do not have any conflict of interest.

REFERENCES

1. American Veterinary Medical Association. [Internet]. https://www.avma.org/.
33. Robb DHF, Kestin SC. Methods used to kill fish: field observations and literature reviewed. Anim Wel. 2002; 11:269-82.
41. The Australian and New Zealand Council for the Care of Animals in Research and Teaching. [Internet]. https://anzccart.org.nz/.