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Short Communication

Quality consequences of bleeding fish after capture

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ABSTRACT

A major cause of downgrading and rejection of fish in the white fish industry is due to discoloration of the fillets because of poor exsanguination. Thus, different bleeding methods and the time elapse between capture and bleeding were evaluated to assess whether different bleeding procedures influences the fillet colour of Atlantic cod (*Gadus morhua*). Visual assessment of the fillet quality and an instrumental method were both used to determine the effects of various bleeding methods on blood residuals and fillet colour. Both the bleeding method and the time elapse (0, 30, 60, 180 min) prior to bleeding influenced the exsanguination. Thus, bleeding reduced the blood residuals and improved the fillet whiteness. However, no clear trends between various methods of bleeding were observed. Compared to direct gutting immediately after capture, better exsanguination ($P < 0.05$) was obtained when the cod was bled immediately and exsanguinated for 30 min prior to gutting (a two-stage method). However, no clear trends between various methods of bleeding were observed. Generally, the time spent from catch to bleeding was the single most important factor influencing proper exsanguination. The results conclude that Atlantic cod should be bled within 30 min after death. When the fish were bled 3 h after death, it was found to be similar to unbled fish in terms of flesh colour.

1. Introduction

The production volume of fresh refrigerated food and the flow of these products are increasing between countries (Kaale et al., 2011). Valuable products, like fresh loins from cod and haddock, require a high quality raw material, without discoloration or gaping. In particular, such products require a raw material that is well drained of blood. Generally, the slaughter method of fish has been based on simplicity and operating expenses. For captured fish, suffocation in air (asphyxia) is one of the oldest methods used to slaughter fish, and is characterized by a prolonged suffering period before death (Poli et al., 2005). Bleeding techniques such as cutting the gill arches, the throat (ventral aorta) or the arteries in the neck (dorsal aorta), and even direct evisceration are frequently used methods to accelerate death and drain the majority of blood from the muscle (Botta et al., 1986; Warriss and Wilkins, 1987; Robb et al., 2000; Borderias and Sanchez-Alonso, 2011). This is often done after suffocation in air to simplify the slaughter process (van de Vis et al., 2003). It has been argued that the most efficient exsanguination is obtained only if the fish is alive during bleeding (Botta et al., 1986; Huss, 1995). However, muscle activity during bleeding is believed to be of less importance to obtain a good exsanguination (Robb et al., 2003; Roth et al., 2005; Olsen et al., 2006, 2008). The time from death to bleeding is considered even more important than the muscle activity during bleeding (Roth et al., 2005, 2009). In addition, some results indicate that muscle activity during bleeding could have an effect on the flesh colour (Digre et al., 2011). The factors limiting the ability to bleed the fish properly are few crew members combined with a high capture efficiency. These are factors that can vary from batch to batch and the quality flaws that are incurred, at this stage, reduce the product quality throughout processing (Botta et al., 1986; Boknaes et al., 2001; Margeirsson et al., 2007; Borderias and Sanchez-Alonso, 2011). It is not unusual that large hauls of fish are kept in storage bins for hours before bleeding and gutting. The last fish out of the storage bin are often dead before bleeding, resulting in insufficient exsanguination and muscle discoloration (Margeirsson et al., 2007; Rotabakk et al., 2011). The capture of wild fish involves various degrees of handling and capture stress; nevertheless, a number of factors can influence the exsanguination and reduce the effect of insufficient bleeding during slaughter (Olsen et al., 2013). In the white fish industry, there is neither a consensus to what is an optimal bleeding method nor a process for the most efficient exsanguination. Therefore, to increase this knowledge on these parameters that influence the bleeding efficiency, this experiment was carried out on recovered and rested fish. Thus, the main

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Table 1
Time intervals from death to bled and different bleeding methods used. Methods No. 1–4 are two-step methods (the fish is bled and exsanguinated for 30 min in water prior to gutting).

	Bleeding methods applied	Time from catch to bleeding			
		0 min	30 min	60 min	180 min
1	Single cut: cut the ventral aorta from the heart	$n=10$	$n=10$	$n=10$	$n=10$
2	Double cut: cut the left and right dorsal aorta	$n=10$	$n=10$	$n=10$	$n=10$
3	Throat cut: slit the throat (ventral and dorsal aorta)	$n=10$	$n=10$	$n=10$	$n=10$
4	Gill-cut; cut the gills arches on one side	$n=10$	$n=10$	$n=10$	$n=10$
5	Direct gutting	$n=20$	$n=20$	$n=20$	$n=20$
6	Unbled (control)	Gutted after 20 h ($n=30$)			

goal was to assess whether different bleeding techniques and the time elapsed between capture and bleeding, influenced the residual blood contents in fillets of wild Atlantic cod (*Gadus morhua*).

2. Materials and methods

Wild Atlantic cod, (2–4 kg) caught by Danish seine, was brought alive to Tromsø Aquaculture Research Station (Tromsø, Norway) in September 2011. At the research station the cod was kept, without food, in large sea cages (500 m^3) to recover for 15 days prior to slaughter. The seawater temperature at slaughter was 11 °C.

2.1. Experimental setup

The fish ($n=270$) was randomly and carefully netted from the sea cages, and then separated into six batches. The fish was killed by a blow to the head and kept in an empty fish tub for 0, 30, 60 and 180 min, prior to bleeding. Five different bleeding methods were applied (Table 1) and the fish ($n=240$) was exsanguinated for 30 min in containers (600 L) with running seawater prior to gutting, beheading and cleaning. Unbled fish ($n=30$) was used as a control group. The fish in the control group was killed with a blow to the head and stored on ice for 20 h prior to gutting. After gutting, the fish was cleaned and carefully packed in polystyrene boxes and covered with ice (8–10 kg ice per 20 kg fish). The fish was laid with the belly cavity downward during ice-storage. This aids in drainage and avoid any distinguishing gravity effect on the blood content in either the left or the right fillets. All the fish was filleted and skinned by hand on day 2. After filleting, the visual assessment of the quality (muscle colour and blood residuals) and the instrumental measurements of the fillet whiteness were carried out.

2.2. Fillet quality score

The evaluators ($n=3$) used in this experiment have extensive training in evaluating the quality of fish. The evaluation was carried out under standardized conditions at room temperature, using electric light and a table provided with white covering. A technician prepared the fish and supplied the judges with coded and randomized fish. The fillet quality score was evaluated, mainly by visual appearance of the fillet, and colour (whiteness), blood filled veins, bruises and bloodstains were taken into consideration (Table 2). The five different bleeding methods and the time elapse from death until bleeding, in min (0, 30, 60 and 180 min), were compared against the control group (unbled and gutted 20 h after death). The overall quality score of the fillet is the sum of scores for all the assessed attributes. A low score represents an excellent quality, and a high score is an unacceptable quality.

Table 2
Fillet quality score for defects because of the slaughtering methods on Atlantic cod fillet. Discoloration (1: homogeneous white, 2: insipient pink, 3: pink/reddish, 4: red translucent). Residual blood (1: no visible blood in veins, 2: some visible blood in 2–4 veins, 3: most of the veins are partly filled with blood, 4: all veins are filled with blood).

	Fillet quality score			
	Flawless	Slightly	Moderate	Severe
Discoloration (loin)	1	2	3	4
Discoloration (belly flap)	1	2	3	4
Residual blood (veins)	1	2	3	4

2.3. Fillet whiteness

The colour and blood volume varies, especially within the fillet, due to differences in muscle thickness and positions. The fillets were therefore divided into two parts, the loin part, which is over the centre line, and the belly part, which is below centre line. A hyperspectral image, in the diffuse reflectance mode, was obtained for each fillet, as described by Sivertsen et al. (2011). The spectra were normalized to relative reflectance (R) with a 99% reflectance Spectralon® Contrast Targets (Labsphere Ltd., North Sutton, NH, USA). The relative reflectance (R) spectra had a value between 1 and 0, where 1 indicated full reflection and 0 indicated complete absorption of light. Based on the colour theory presented in Wyszecki and Stiles (1982), the reflectance spectra were transformed into Lab-values using daylight (D65), illumination and a CIE 1964 (10°) Standard Observer. For each fillet, two Lab-values were calculated: one from the loin area and the other from the belly area. Fig. 1 shows how the sampling was carried out. The mean value, indicated on the fillets, was brought forth from the elliptical

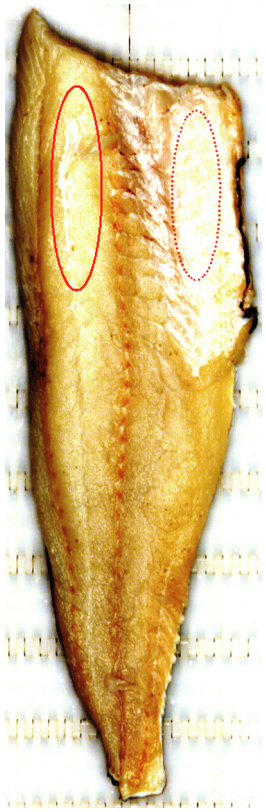

Fig. 1. A synthetic colour image (B = 460 nm, G = 565 nm, R = 615 nm) of a fillet. The fillet whiteness was calculated as the mean value, brought forth from the red elliptical area indicated on the fillet.