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Physicochemical characteristics of fillet in commercial freshwater farm- Rainbow trout (*Oncorynchus mykiss*) subjected to two different slaughter methods

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ABSTRACT

This experiment was conducted to study the effect of two slaughter methods on physicochemical characteristics of fillet in commercial freshwater farm-Rainbow trout (*Oncorynchus mykiss*). Forty immature fish were caught and slaughtered by either decapitation immediately after capture (Decapitation group; n = 20), and asphyxia in the air (Asphyxia group; n = 20). All Fish were placed on ice for 30 minutes and then set into a polystyrene tray, wrapped in an oxygen permeable film and stored at 4°C for measurements. pH, texture (PND: Penotrometer needle depth in mm), color (luminance: L*, redness: a* and yellowness: b*) and water holding capacity (drip loss, thawing loss and cooking loss) were measured in fillet of fish at different times *post mortem*. At 20 and 45 minutes and 1 hour *post mortem*, pH mean values were significantly lower in Asphyxia Rainbow trout group than in Decapitation group (6.56 ± 0.05, 6.39 ± 0.05 and 6.26 ± 0.05 *Vs* 6.71 ± 0.05, 6.63 ± 0.04 and 6.51 ± 0.04 at 20 and 45 minutes and 1 hour *post mortem* ($P < 0.05$ and *0.01*) respectively. However, no differences were detected in the extent of *post mortem* pH decline between Asphyxia and Decapitation groups ($P > 0.05$). In Decapitation group meat hardness increased significantly ($P< 0.05$) from 20 minutes to 2 hours *post mortem*. After that, the tenderness of meat increased significantly ($P< 0.05$) until 10 hours *post mortem*. In Asphyxia group, meat hardness increased significantly ($P< 0.05$) from 20 minutes to 1 hour *post mortem*. After that, the tenderness of meat increased significantly ($P< 0.05$) until 6 hours *post mortem*. These results suggested that Rainbow trout fish killed by asphyxia (higher muscle activity, excitement, pain or suffering before and / or during slaughter) had faster glycolysis and resolution of *Rigor mortis* than those sacrificed by decapitation. Regarding meat quality traits, neither the color (L*, a* and b*) nor drip loss (measured at 24 and 48 hours *post mortem*) and thawing loss were significantly different between Asphyxia and Decapitation groups. Whereas, cooking loss and tenderness of cooked meat were significantly different between the two groups (Asphyxia and Decapitation groups), ($P < 0.05$); fish killed by asphyxia had a higher cooking loss and a clearly lower PND mean value than those sacrificed by decapitation (19.36 ± 0.95 *Vs*16.23 ± 0.86 for cooking loss and 16.97 ± 0.45 *Vs* 18.29 ± 0.52 for PND; $P < 0.05$). Due to the scarcity of information in this area of research, farther investigations are needed to improve the capacity of controlling freshwater meat quality.

Key words: Asphyxia, decapitation, pH, *Rigor mortis*, meat ageing, meat quality, Rainbow trout fillet.

INTRODUCTION

It has been recognized that an increase in muscular activity, stress and relative endocrine response (epinephrine secretion) induce changes in muscle metabolism, mostly in anaerobic glycolysis and ATP degradation rate. This can markedly influence the onset of *Rigor mortis* and meat ageing, which in turn affects negatively the meat quality and durability of the product [23]. Fish stress directly before death and or during slaughter can impact meat quality, by depleting glycogen before *Rigor*, leading to an earlier *Rigor mortis* and a rapid *post mortem* pH decline. Rapid *post mortem* glycolysis, the early onset of *Rigor mortis* and a fast decline in muscle pH, while carcass temperatures are still high, provoke precipitation of sarcoplasmic and myofibrillar proteins (denaturation of proteins: loss of functionality and water binding ability) and reduction in the water holding capacity leading to a soft, pale and exsudative meat [24]. Soft, pale and exsudative meat can occur, for example, when the capture process is very traumatic (struggling and crowding) and fish are left to die in the air by asphyxia (characterized by a prolonged suffering period before death). Fish stress, hours before death, can impact meat quality, by a higher final pH value in the muscle, leading to firm and dry meat [24]. Firm and dry meat can occur, for example, when traumatic pre-slaughter situation lasts for a longer time (*i.e.* repeated catching), the lactic acid produced will be gradually cleared from the blood and muscle [19], but the energy sources will become gradually exhausted.

Various methods of slaughter are used in fish farms; such as death in air or asphyxia (traditionally used for capturing fish and consist in leaving fish to die out of water), death in ice slurry (immersion in water plus ice, fish die of anoxia), CO_2 narcosis (immersion in water saturated by CO_2), electrical stunning (1 second of electricity applied across the head), percussion (sharp blow to the head

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immediately after capture) and decapitation. It is generally assumed that slaughter methods are stressful for fish and can affect negatively meat quality in a similar fashion to mammals and poultry [13,24]. Because stressors can only be reduced rather than completely avoided, slaughtering fish by a suitable method (with minimum muscle activity, excitement, pain or suffering) is very important to provide better meat quality as well as protecting animal welfare. Effects of slaughter methods on quality have been widely studied in fish. Various experiments with the aim of finding a practical low stress slaughtering method and the best quality of fish fillet meat were carried out by several authors [1,32,18]. However, published results on this topic appear in some respect contradictory and further work in this area of research would be very useful to improve the capacity of controlling meat quality in fish.

Therefore, the present experiment was carried out to study the effect of two different slaughter methods on physicochemical characteristics of fillet in commercial freshwater farm-Rainbow trout (*Oncorynchus mykiss*).

Materials and Methods

Fish:

Forty fish "with an average live body weight of 1.3 +/- 0.16 kg" were randomly trapped and captured from a population of 1000 Rainbow trout (*Oncorynchus mykiss*) and used in the present study. None of the fish selected were maturing and all had been fed a commercial trout diet. They were captured by a net and slaughtered by either decapitation immediately after capture (Decapitation group; n = 20) and asphyxia in the air (Asphyxia group; n = 20). All Fish of both groups were placed on ice for 30 minutes and then set into a polystyrene tray, wrapped in an oxygen permeable film and stored at 4°C for measurements.

Muscle sampling:

The left fillet of each experimental fish was used to measure *Rigor mortis* development: Evolution of *post mortem* pH and raw meat texture and buffering capacity, whereas the right fillet was used in meat quality measurements; color, water holding capacity (drip loss, thawing loss and cooking loss) and cooked meat texture. At twenty-four hours *post mortem*, right fillets were removed from the experiment fish. Two slices of approximately 105 g each with similar size and shape were cut from the right fillet; one slice was used for the measurement of color and drip loss at 24 and 48 hours *post mortem*, while the other one vacuum- packed and stored in a freezer at - 30°C for 7 days for the determination of thawing loss, cooking loss and texture of cooked meat. Muscle samples were obtained as it is shown in **Figure 1**.

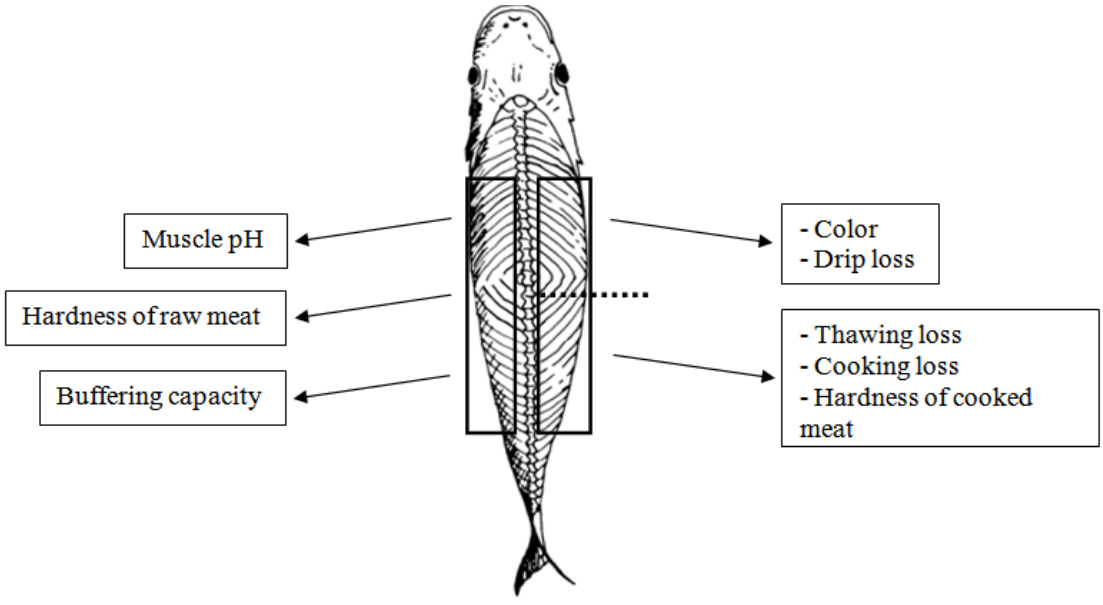

Fig. 1: Muscle sampling

pH measurements:

At different times *post mortem*; 20 and 45 minutes and 1, 2, 6, 10 and 24 hours, muscle slices of 2 g each were removed from left fillet and immediately homogenized in 18 ml of 5 m*M* iodoacetate buffer [16] The pH of the homogenate was measured using a portable pH meter (HI 8424 Microprocessor pH Meter, HANNA Instruments, Woonsocket, RI.) equipped with a combined electrode.

Buffering capacity:

Samples collected from left fillet at 6 hours *post mortem* were immediately frozen in carbon glass and kept at - 30°C until used. Buffering capacity of fillet was measured as described by [20]. Muscle sample of five grams each were homogenized in 50 mL of 0.05 *M* iodoacetate. The pH of the homogenate was adjusted to 4.8 with 0.1 *N* HCl. Then, 200 μL of 0.5 *N* NaOH was added every 2 minutes until pH 7 was reached. The change in pH value was recorded after each addition of NaOH. The buffering capacity was calculated as the slope of the titration curve between pH 5.2 and 6.5 and expressed as millimoles of H^+ per kilogram of muscle per unit of pH.

Meat texture measurements:

At 20 and 45 minutes and 1, 2, 6, 10 and 24 hours *post mortem*, raw meat texture was measured using a penetrometer (interface RS232C) with a needle of 2.5 g based on a weight of 47.5 g, thus attaining a total weight of 50 g. The penetration was carried out on meat slices (3 cm x 2 cm x 1 cm) prepared such that the longest dimension was parallel to the fiber axis. The slices were placed on a horizontal support and the force of the needle was applied perpendicularly to the muscle fibers for 5 seconds [4]. The penetrometer needle depth (PND; in mm) was recorded and an average of 3 replications by sample was calculated. The same procedure was done on meat cooked after 7 days of freezing.

Color measurements:

At 24 and 48 hours *post mortem*, meat color was determined using a chromameter (ADCI - 60 - C). The instrument was set to measure using the CIE system (International Commission on Illumination; abbreviated CIE for its French name) values of luminance (L*), redness (a*), and yellowness (b*) using illuminate D and 65° standard observer (C. I.E., 1978). All measurements (3 replicates on each fillet) were carried out on the surface of the right fillet, in an area free of obvious color defects (over scalding, blood spots, and hemorrhages).

Drip loss:

Drip loss was determined by the method of [21]. Right raw fillets were weighed at 24 hours *post mortem*, placed in a polystyrene tray, wrapped in an oxygen permeable film and kept at 4°C for the 2nd day. Fillets were reweighed at 48 hours *post mortem* and the drip loss was expressed as percentage of initial weight.

Thawing and cooking loss:

After 12 hours thawing in a refrigerator at 4°C, fillets were taken from bags, dried with filter paper, and reweighed before cooking. Thawing loss was expressed as a percentage of the frozen weight.

Cooking loss was determined immediately after thawing in meat samples vacuum packed in polyethylene bags and cooked in a water bath at 80°C for 15 minutes (corresponding to an internal temperature of 70°C; [15]). Care was taken to ensure that all samples were of similar dimensions. Samples were cooled for 45 minutes under running tap water at room temperature. After that, they were taken from the bags, dried with filter paper and weighed. Cooking loss was expressed as the percentage loss relative to the weight immediately before cooking.

Statistical analysis:

ANOVA was carried out using the GLM procedure of SAS [30]. The model included the effect of two methods of slaughter. When significant effects were recorded, mean values were compared using Duncan's multiple range tests. Significant levels were reported at $P < 0.05$ * and $P < 0.01$ **.

Results and Discussion

pH changes in post mortem *muscle:*

Post mortem pH changes in fillet of Rainbow trout fish subjected to two different methods of slaughter are shown in **Figure 2**. The rate of *post mortem* pH fall in raw fillet of Rainbow trout was significantly higher ($P < 0.01$) in fish slaughtered by asphyxia (Asphyxia group) than those killed immediately after capture by decapitation (Decapitation group). At 20 and 45 minutes and 1 hour *post mortem*, pH mean values were significantly lower in Asphyxia Rainbow trout group than in Decapitation group (6.56 ± 0.05, 6.39 ± 0.05 and 6.26 ± 0.05 in Asphyxia group *Vs* 6.71 ± 0.05, 6.63 ± 0.04 and 6.51 ± 0.04 in Decapitation group at 20 and 45 minutes and 1 hour *post mortem* $P < 0.05$ and *0.01*). However, the slaughter method did not affect the extent of *post mortem* pH decline; at 2, 6, 10 and 24 hours *post mortem* no significant differences in pH mean values were found between Asphyxia and Decapitation groups. The lack of relationship between the rate and the extent of *post mortem* pH fall is not surprising since these two parameters are determined by different factors. The extent of *post mortem* pH decline is mainly determined by the content of muscle glycogen at slaughter [5] while the rate of *post mortem* pH fall is determined by the rate of ATP hydrolysis, as shown by [31] using cell free glycolysing system. In agreement with this statement, Lowe *et al*. [17] showed that fish (Australasian Snapper fish) exhibiting a high level of activity at slaughter time had a faster drop of *post mortem* fillet pH, with a normal extent of pH fall.

When studying meat quality in Rainbow trout, Robb *et al*. [27] published that anaesthetized fish show a slow rate of *post mortem* muscle pH fall (starting at 7.8 ± 0.03 and dropping below 6.60 after 45 hours), whereas electro-stimulated fish show a rapid drop in pH (starting at 6.7 ± 0.03 and dropping below 6.60 after 2.5 hours). Indeed, high muscular activity and fatigue with catecholamine release (stress hormones: epinephrine), as a result of fear and excitement (stress), induces an excessive proton H^+ and lactic acid production in muscle and consequently leads to rapid glycolysis and *post mortem* pH fall [8]. Under conditions of our experiment, it could be concluded that fish left out of the water to die by asphyxia, suffer and exhibit a high level of muscle activity and fatigue leading to rapid ATP hydrolysis and *post mortem* pH fall. However, slaughtering methods by asphyxia or by decapitation had no effects on ultimate pH values in fillet of Rainbow trout because no significant differences were recorded in ultimate pH values between Asphyxia and Decapitation groups. This point needs further investigations in Rainbow trout fish, since several studies conducted on meat of different species reported that pre-slaughter stresses affect significantly the ultimate pH in duck [9], in Rainbow trout Sebastio *et al*. [32] and Robb *et al*. [27], in quail Remignon *et al*. [26]. Additionally, it should be noted that, in the current study, the apparent ultimate pH of Rainbow trout fillet was reached after 2 hours *post mortem*. Result in agreement with the previous finding of El Rammouz *et al*. [11] who showed that Rainbow trout meat pH fall was stabilized at values between 6.30 and 6.20 after 2 hours *post mortem*.

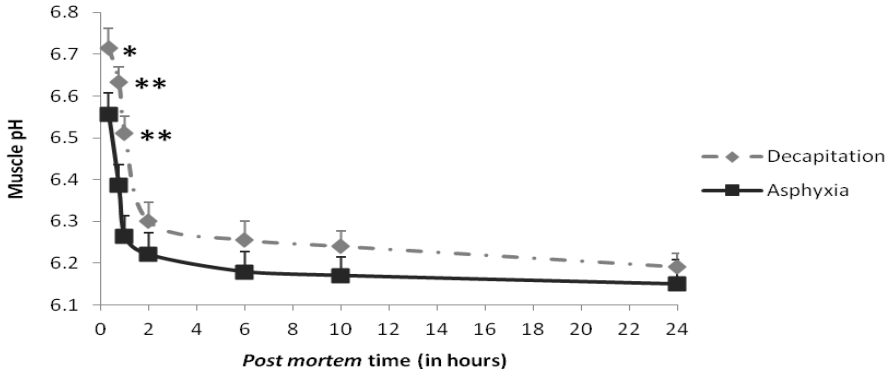

Fig. 2: pH changes in *post mortem* fillet of Rainbow trout within 2 methods of slaughter (n = 40).

Decapitation = immediately killed after capture; Asphyxia = death in the air. *, ** = $P < 0.05$ and $P < 0.01$ respectively. Vertical bars show SEM.

Rigor mortis and meat ageing:

Figure 3 illustrates *post mortem* changes of meat tenderness in fillet of Rainbow trout subjected to two different methods of slaughter. The conditions under which PND measurements (Penetrometer needle depth) have been performed in the present study provide information on *Rigor mortis* and ageing state of the meat. In Decapitation group, meat hardness increased significantly ($P< 0.05$) from 20 minutes to 2 hours *post mortem*. After that, the tenderness of meat increased significantly ($P< 0.05$) until 10 hours *post mortem*. At twenty and forty five minutes, one and 2 hours *post mortem* the fillet PND mean values were 12.31 ± 0.22, 10.34 ± 0.36, 10.40 ± 0.51 and 10.25 ± 0.50, respectively, with no statistical differences between values at 45 minutes, 1 and 2 hours *post mortem*. After that, PND values increased significantly ($P< 0.05$) to 11.61 ± 0.18 at 6 hours *post mortem* and to 12.74 ± 0.22 and 12.89 ± 0.26 at 10 and 24 hours *post mortem*, respectively. In Asphyxia group, meat hardness increased significantly ($P< 0.05$) from 20 minutes to 1 hour *post mortem*. After that, the tenderness of meat increased significantly ($P< 0.05$) until 6 hours *post mortem*. At twenty and forty five minutes and one hour *post mortem* the fillet PND mean values were 11.99 ± 0.22, 10.80 ± 0.26 and 10.70 ± 0.37 respectively, with no statistical differences between values at 45 minutes and one hour *post mortem*. After that, PND values increased significantly ($P< 0.05$) to 11.47 ± 0.39 and 12.58 ± 0.22 at 2 and 6 hours *post mortem* and to 12.75 ± 0.22 and 13.01 ± 0.51 at 10 and 24 hours *post mortem*, respectively. These findings suggested that the time of *Rigor mortis* establishment in fillet of Rainbow trout is shorter when fish are killed by asphyxia than those slaughtered immediately after capture by decapitation (one hour *Vs* 2 hours *post mortem*, respectively). This result was consistent with the finding that the rate of *post mortem* pH fall was higher in fish killed by asphyxia than in Decapitation group (see Figure 2). Furthermore, the current result is in agreement with the observation of Sebastio *et*

al. [32] who reported that Rainbow trout fish killed by asphyxia showed a shorter *rigor mortis* than those slaughtered by CO_2 narcosis and percussive and electrical stunning. Indeed, when anaerobic glycolysis ceased, the pH decline stop as well as the producing of adenosine triphosphate (ATP); actin and myosin form rigid chain causes stiffness and inextensible state of muscle [3]. The moment at which this state is reached depends on the metabolic state of the muscle at death and the *post mortem* glycolytic rate in the muscle [13]. Increasing exercise, immediately *ante mortem*, induces rapid glycolysis and *post mortem* pH fall and consequently leads to a faster onset and establishment of *Rigor mortis* [6,33,23]. In the present trial, it could be hypothesized that fish left to die by asphyxia, suffer and exhibit a high level of muscle activity leading to rapid ATP hydrolysis, *post mortem* pH fall and *Rigor mortis* establishment. Such observations have been reported in fillet of Rainbow trout by Robb *et al*. [27] who claimed that onset and establishment of *Rigor mortis* are faster in electro-stimulated than anesthetized fish. Moreover, in a study conducted on Rainbow trout and Mirror carp physical quality, Duran *et al*. [10] showed that onset and establishment of *Rigor mortis* are faster in fish killed by asphyxia than those sacrificed by decapitation.

After the establishment of *Rigor mortis*, meat ageing occurs. In contradiction with the *Rigor*, meat ageing or maturation of meat is associated with an improvement in tenderness [25]. In the present study, the effect of two slaughter methods on meat ageing in fillet of Rainbow trout was studied. Current results showed that, in Decapitation group, meat maturation occurs at about 2 hours *post mortem* and finishes at 10 hours after death. Whereas, meat ageing begins at one hour *post mortem* and achieves at 6 hours after death in Asphyxia group (see Figure 3). However, no differences were detected in the extent of meat maturation between Asphyxia and Decapitation groups; at 10 and 24 hours *post mortem* no significant differences in PND mean values were found between Asphyxia and Decapitation groups.

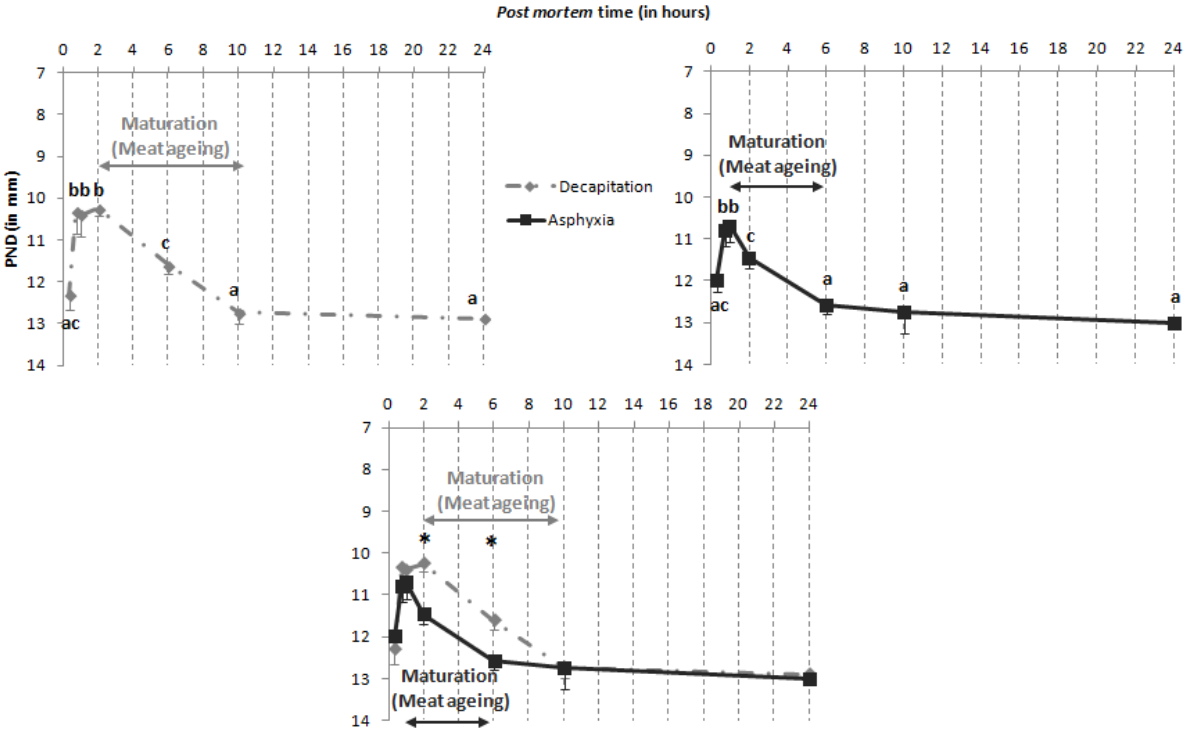

Fig. 3: *Post mortem* changes of meat tenderness in fillet of Rainbow trout within 2 methods of slaughter (n = 40).

Decapitation = immediately killed after capture; Asphyxia = death in the air; PND = Penetrometer Needle Depth. $^{a-c}$ different letters indicate significant differences ($P< 0.05$). Vertical bars show SEM. * = $P < 0.05$.

To the best of our knowledge, previous data on this subject are scarce in fish. Recently, El Rammouz *et al*. [11] stated that meat ageing of Rainbow trout, killed and eviscerated immediately after capture, occurs in the early stage of *post mortem* storage (2 to 5 hours after death) and achieved at about 10 hours *post mortem*. However, these authors did not study the effect of slaughter methods or/ and slaughter stresses on *Rigor mortis* and meat ageing. In Awassi sheep, El Rammouz *et al*. [11], (unpublished data)

did not find a clear effect of *ante mortem* stresses on *Rigor mortis* and meat ageing of *Biceps femoris* muscle.

Meat quality traits:

Color measurements (CIE: L*, a* and b*) in raw fillet of Rainbow trout within the two methods of slaughter (Decapitation and Asphyxia) are shown in **Figure 4**. The Luminance of meat (L*), indicating superficial light scattering, generally depends on the rate and extent of *post mortem* pH fall. Whereas, the a* / b* ratio, considered as an indicator of myoglobin oxidation is related, in part, to the rate of *post mortem* pH fall and is generally decreased in fast glycolysis [29]. When the rate of *post mortem* pH fall increases and ultimate pH decreases, the luminance (L*) and the yellowness (b*) values increase, contributing to a paler appearance of the meat [22,12]. Warriss [34] reported that L* and b* values are increased in red meat animals subjected to high levels of muscle activity prior to slaughter. This author asserted that, in stressed animals, rapid *post mortem* glycolysis and fast decline in muscle pH when carcass temperatures are still high result in extensive protein denaturation, a poor water holding capacity and consequently paler appearance of the meat with higher L* an b* values. In agreement with this assertion, Robb *et al*. [27] claimed that electro-stimulated Rainbow trout exhibit significant higher L* values than anesthetized fish. However, when studying effect of different slaughter methods on product quality in Catfish, Boggess *et al*., [7] did not show significant differences in L* values between fish killed in ice slurry or by electric chock. Similarly, Scherer *et al*. [28] also found no effect of slaughter methods on L* and a* values in Grass carp stored in ice. The present work showed that trichromatic coordinates (L*, a* and b*) and a* / b* ratios were not related to the rate of *post mortem* pH fall. Although the rate of *post mortem* pH decline was higher in Asphyxia group than Decapitation group, slaughter methods (Decapitation and Asphyxia) did not affect trichromatic coordinates (L*, a* and b*) and a* / b* ratios. The lack of relationship between the rate of *post mortem* muscle pH fall and CIE color readings (L*, a* and b*) throughout the current experiment is unknown. Due to the scarcity of information in this area of research, further investigations are needed to determine the relationship between color and the rate and the extent of *post mortem* pH fall in fillet of rainbow trout.

Experimental results obtained on water holding capacity of meat in Rainbow trout subjected to two slaughter methods are presented in Table 1. Exposing fish to acute stress just before death or / and during slaughter, can impact meat quality, leading to an earlier *Rigor* and a rapid *post mortem* pH fall. Accelerated pH decline causes precipitation of sarcoplasmic and myofibrillar proteins (loss of functionality and water binding ability) leading to reduction in water holding capacity [24]. When studying impact of slaughter methods on meat quality in freshwater fish (trout, carp and eel), Marx *et al*. [18] reported similar results of Poli *et al*. [24]. They observed a rapid pH decline and a low water holding capacity in fish killed after CO_2 narcosis than those sacrificed after anesthetizing. In the present work, drip loss (measured at 24 and 48 hours *post mortem*) and thawing loss were not influenced by the slaughter method. However, cooking loss was significantly higher in fillet of fish killed by asphyxia than those sacrificed by decapitation immediately after capture (19.36 ± 0.95 and 16.23 ± 0.86; $P < 0.05$). The only explanation for this surprising result is that the effect of the rate of *post mortem* pH decline on cooking loss was exacerbated by our experimental cooking conditions leading to a higher cooking loss in Asphyxia group than in Decapitation group.

Results illustrating PND cooked meat values within the two methods of slaughter under this study are presented in Figure 5. These data indicate that PND values of cooked meat were significantly different between the two methods of slaughter ($P < 0.05$). Fish killed immediately after capture by decapitation (Decapitation group) had a clearly higher PND mean value than those sacrificed by asphyxia (Asphyxia group), (18.29 ± 0.52 *Vs* 16.97 ± 0.45; $P < 0.05$). In agreement with the result of the present experiment, Poli *et al*. [24] published that stresses prior to slaughter affected negatively the texture of meat in fish. Ang and Haard [2] and Foegeding *et al*. (1996) reported that the rate of *post mortem* pH decline is very important since rapid pH fall causes poor water holding capacity and soft texture of fish meat. However, it is worth to mention that in the present trial high muscle activity prior to slaughter (Asphyxia group) affects only the tenderness of cooked meat; no significant differences in PND values of raw fillet texture were recorded between Asphyxia and Decapitation groups (see Figure 3). To the best of our knowledge, experimental data concerning the effect of slaughter methods on cooked meat tenderness in fillet of Rainbow trout are scarce. Recently, El Rammouz *et al*. [11] examined the effect of sex and live body on texture of cooked fillet in Rainbow trout. However, these authors did not study the effect of stress before and during slaughter on tenderness of cooked meat.

Finally, Table 2 shows the influence of two different slaughter methods on all parameters measured under the present study.

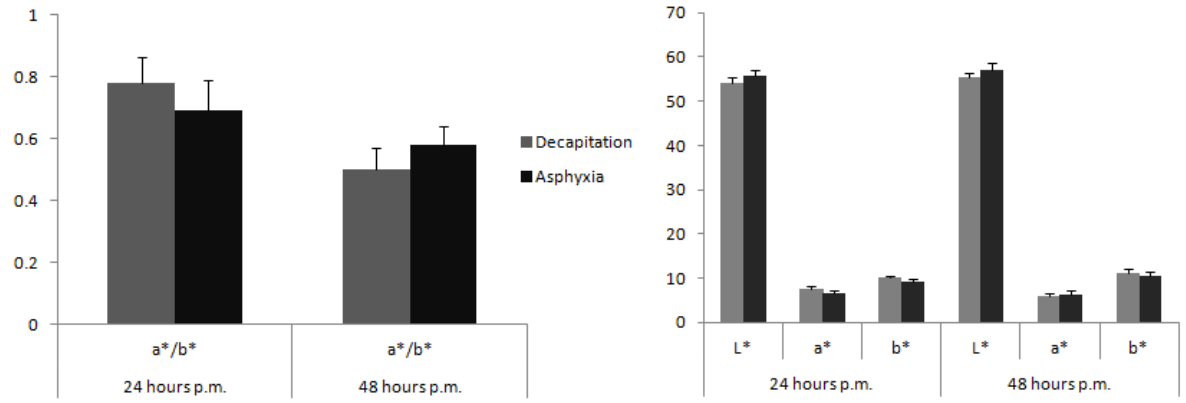

Fig. 4: Effect of two methods of slaughter on color of raw fillet in Rainbow trout (n = 40).

Decapitation = immediately killed after capture; Asphyxia = death in the air; L*, a*, b* = CIE luminance, redness and yellowness of filet; p.m. = *post mortem*. Vertical bars show SEM.

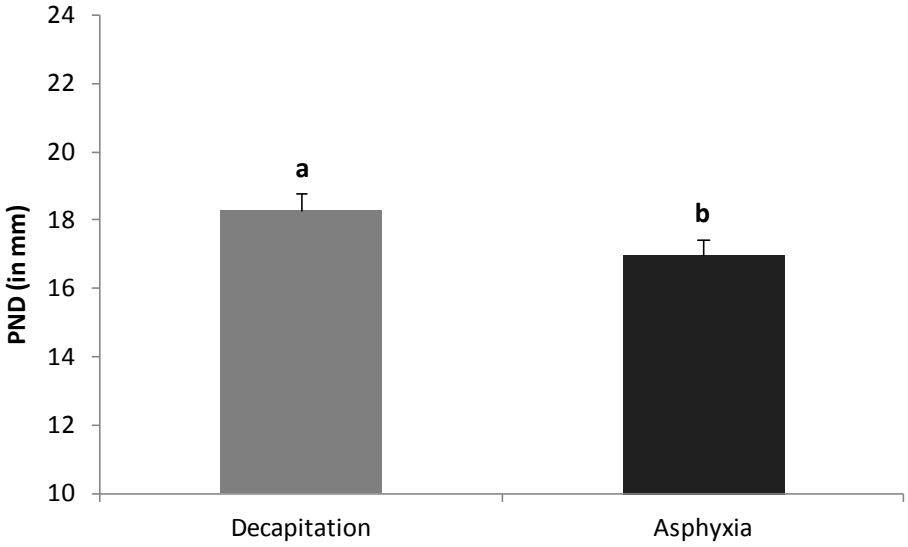

Fig. 5: Effect of two methods of slaughter on tenderness of cooked meat in fillet of Rainbow trout (n = 40).

Decapitation = immediately killed after capture; Asphyxia = death in the air; PND = penetrometer needle depth. [a- b] different letters indicate significant differences (*P< 0.05*). Vertical bars show SEM.

Table 1: Effect of two different slaughter methods on water holding capacity (WHC) of meat in Rainbow trout (n = 40)[1].

WHC variables	Slaughter method		Significance
	Decapitation	Asphyxia	
Drip loss 24 h *p.m.* (%)	0.56±0.06	0.58±0.04	NS
Drip loss 48 h *p.m.* (%)	1.73± 0.19	1.63±0.11	NS
Thawing loss (%)	2.58±0.30	2.58±0.19	NS
Cooking loss (%)	16.23±0.86**a**	19.36±0.95**b**	*

[1] Values are means ± SEM (Standard error of the mean); WHC = water holding capacity; Decapitation = immediately killed after capture; Asphyxia = death in the air; h = hours; *p.m.* = *post mortem.* [a- b] Means within a row with differing letters are significantly different; * = *P < 0.05*; *NS* = Not Significant.

Table 2: Influence of two different slaughter methods on physicochemical characteristics of fillet in Rainbow trout (n = 40).

Variables[1]	Different slaughter methods (Decapitation / Asphyxia)
Post mortem pH	
At 20 minutes	*
At 45 minutes	**
At 1 hour	**
At 2 hours	NS
At 6 hours	NS
At 10 hours	NS
At 24 hours	NS

Buffering capacity	
At 6 hours *p.m.*	NS
Raw meat texture	
PND at 20 minutes	NS
PND at 45 minutes	NS
PND at 1 hour	NS
PND at 2 hours	*
PND at 6 hours	*
PND at 10 hours	NS
PND at 24 hours	NS
Meat color at 24 hours *p.m.*	
L*	NS
a*	NS
b*	NS
Meat color at 48 hours *p.m.*	
L*	NS
a*	NS
b*	NS
WHC variables	
Drip loss at 24 hours *p.m.* (%)	NS
Drip loss at 48 hours *p.m.* (%)	NS
Thawing loss (%)	NS
Cooking loss (%)	*
Cooked meat texture	
PND	*

[1] Decapitation = immediately killed after capture; Asphyxia = death in the air; PND = Penetrometer Needle Depth (in mm); L*, a*, b* = CIE luminance, redness and yellowness of filet; WHC = Water Holding Capacity. ** $P < 0.01$; * $P < 0.05$ and NS = $P > 0.10$.

Conclusion:

Results of this study showed the effect of two slaughter methods on the rate and the extent of *post mortem* muscle pH fall, *Rigor mortis,* meat ageing and meat quality in fillet of Rainbow trout. The present work indicated that fish killed by asphyxia exhibit a significantly high rate of *post mortem* pH fall than Rainbow trout fish sacrificed by decapitation; however, no differences were detected in the ultimate pH between the two methods of slaughter under the present experiment. Moreover, fish killed by asphyxia (Asphyxia group), had faster *Rigor mortis* and meat ageing than those sacrificed immediately after capture by decapitation (Decapitation group). Concerning meat color and water holding capacity, our study did not support the hypothesis that fast drop of *post mortem* pH causes high values of L* and b* and poor water holding capacity. Only, meat cooking loss was significantly affected. Finally, the current experiment showed that high muscle activity before and / or during slaughter (Asphyxia group) affects negatively the tenderness of cooked meat in fillet of Rainbow trout. Due to the scarcity of information in this area of research, further investigations are needed to improve the capacity of controlling freshwater meat quality.

Abbreviations:

a*	CIE redness value
ATP	Adenosine triphosphate
b*	CIE yellowness value
CIE	International Commission on Illumination; Commission internationale d'éclairage
L*	CIE Luminance (lightness) value
p.m.	*Post mortem*
PND	Penetrometer needle depth
SEM	Standard error of the mean
WHC	Water holding capacity

References

1. Azam, K., M. Mackie and J. Smith, 1989. The effect of slaughter method on the quality of rainbow trout (*Salmo gairdneri*) during storage on ice. International Journal of Food Science and Technology, 24: 69-79.
2. Ang, J.F., and N.F. Haard 1985. Chemical composition and postmortem changes in soft textured muscle from intensely feeding Atlantic cod (*Gadius morhua*, L). Journal of Food Biochemistry, 9(1): 49-64.
3. Bate-Smith, E. C. and J. R. Bendall, 1947. *Rigor mortis* and adenosine triphosphate. Journal of physiology, 106(2): 177-185.
4. Becila, S., 2002. Étude de l'influence des parameters physico- chimiques sur la maturation de la viande d'agneau. M.S. thesis, Institut de la Nutrition, de l'Alimentation et des Technologies Agro- Alimentaires (INATAA), Mentouri University, Connstantine, Algeria, pp. 105.
5. Bendall, J.R., 1973. Post mortem changes in muscle. In Structure and Function of Muscle, G.H. Bourne, ed. Academic Press, New York, USA, pp: 275.

6. Berg, T., U. Erikson and T.S. Nordvedt, 1997. Rigor mortis assessment of Atlantic salmon *Salmo salar* and effects of stress. Journal of Food Science, 62: 439-446.
7. Boggess, T.S., E.K. Heaton, A.L. Shewfelt and D.W. Parvin, 1973. Techniques for stunning channel catfish and their effects on product quality. Journal of Food Science, 38: 1190-1193.
8. Cassens, R.G., D.N. Marple and G. Eikelenboom, 1975. Animal Physiology and Meat Quality. Advances in Food Research, 21: 71-155.
9. Chen, M-T., S-S. Lin, and L-C. Lin, 1991. Effect of stresses before slaughter on changes to the physiologica, biochemical, and physical characteristics of duck muscle. British Poultry Science, 32: 997-1004.
10. Duran, A., U. Erdemli, M. Karakaya and M. Tyilmaz, 2008. Effects of slaughter methods on physical, biochemical and microbiological quality of rainbow trout *Oncorhynchus mykiss* and mirror carp *Cyprinus carpio* filleted in pre-, in- or post-rigor periods. Fisheries Science, 74(5): 1146-1156.
11. El Rammouz, R., J. El Rammouz, M. Abboud, A. El Mur, S. Yammine and B. Jammal, 2013. pH, *Rigor mortis* and physical properties of fillet in fresh water fish: The case of Rainbow trout (*Oncorynchus mykiss*). Submitted to Journal of Applied Sciences Research.
12. El Rammouz, R., R. Babilé and X. Fernandez, 2004. Effect of ulimate pH on the physicochemical and biochemical characteristics of turkey breast muscle showing normal rate of *post mortem* pH fall. Poultry Science, 83: 1750-1757.
13. Erikson, U., 1997. Muscle quality of Atlantic salmon (*Salmo salar*) as affected by handling stress. Ph.D. Thesis, Norwegian University of Science and Technology, Trondheim, Norway, pp: 132.
14. Foegeding, E.A., T.C. Lanier and H.O. Hultin, 1996. Characteristics of edible muscle tissues. In Food Chemistry Third edition, O.R. Fennema, ed. New York, USA: Marcel Dekker, Inc, pp: 1067.
15. Honikel, K.O., 1998. Reference Methods for the Assessment of Physical Characteristics in Meat. Meat Science, 49: 447-457.
16. Jeacocke, R.E., 1977. Continuous Measurement of the pH of Beef Muscle in Intact Beef Carcass. Journal of Food Technology, 12: 375-386.
17. Lowe, T.E., J.M. Ryder, J.F. Carragher and R.M.G. Wells, 1993. Flesh quality in snapper, *Pagrus auratus*, affected by capture stress. Journal of Food Science, 58: 770-796.
18. Marx, H., B. Brunner, W. Weinzierl, R. Hoffman and A. Stolle, 1997. Methods of stunning freshwater fish: impact on meat quality and aspects of animal welfare. Zeitschrift fur Lebenschmittel Untersuchung und Forschung, 204: 282-286.
19. Milligan, C.L., 1996. Metabolic recovery from exhaustive exercise in rainbow trout. Comparative Biochemistry and Physiologie, 113A(1): 51-60.
20. Monin, G. and P. Sellier, 1985. Pork of low technological quality with a normal rate of muscle pH fall in the immediate *Post mortem* period: The case of the Hampshire breed. Meat Science, 13: 49-63.
21. Offer, G., and P. Knight, 1988. The Structural Basis of Water-Holding in Meat. General Principles and Water Uptake in Meat Processing. In Developments in Meat Science. Elsevier Applied Science Publishing Co., Inc., New York, NY, pp. 362.
22. Owens, C.M., E.M. Hirschler, S.R. McKee, R. Martinez-Dawson and A.R. Sams, 2000. The characterization and incident of pale, soft, exsudative turkey meat in a commercial plant. Poultry Science, 78: 553-558.
23. Parisi, G., M. Mecatti, P. Lupi, F. Scappini, and B.M. Poli, 2002. Comparison of five slaughter methods for European sea bass. Changes of isometric contraction force and pH during the first 24 hours post mortem. In the Proceedings of the Aquaculture Europe 2002: Sea Farming Today and Tomorrow, pp: 417-418.
24. Poli, B.M., G. Parisi, F. Scappini and G. Zampacavallo, 2005. Fish welfare and quality as affected by pre-slaughterand slaughter management. Aquaculture International, 13: 29-49
25. Redmond, G.A., B. McGeehin, J.J. Sheridan and F. Butler, 2001. The effect of ultra-rapid chilling and subsequent ageing on the calpain/ calpastatin system and myofibrillar degradation in lamb M. *Longissimus thoracis et lumborum*. Meat science, 59: 293-301.
26. Remignon, H., A.D. Mills, D. Guemene, V. Desrosiers, M. Garreau-Mills, M. Marche, and G. Marche, 1998. Meat quality traits and muscle characteristics in high or low fear lines of Japanese quails (*Coturnix japonica*) subjected to acute stress. British poultry Science, 39: 372-378.
27. Robb, D.H.F., S.C. Kestin and P.D. Warriss, 2000. Muscle activity at slaughter: I. Changes in flesh colour and gaping in rainbow trout. Aquaculture, 182: 261-269.
28. Scherer, R., P.R. Augusti, C. Steffens, V.C. Bochi, L.H. Heckttheuer, R. Lazzari, J. Radunz-Neto, S.C.G. Pomblum and T. Emanuelli, 2005. Effect of slaughter method on *post mortem* changes of Grass carp (*Ctenopharyngodon idella*) stored in ice. Journal of Food Science, 70(5): 348-353.
29. Santé, V., 1993. Instabilité de la couleur de la viande de dinde (*Meleagris gallopavo*) :

influence de la *Rigor mortis*, du mode de conditionnement et d'antioxidants. Ph.D. thesis. Université Clermont II, France, pp: 132.
30. SAS Institute, 1989. SAS/STAT® User's Guide for Personal Computers. Release 6.03. SAS Institute Inc., Cary, NC.
31. Scopes, R.K., 1971. The biochemistry of post mortem glycolysis. In the Proceedings of the 17th European Meeting of Meat Research Workers, U K, Bristol, pp. 14-20.
32. Sebastio, P., F. Ambroggi and G. Baldrati, 1996. Influenza del sistema di sacrificazione su trote iridee di allevamento. I Considerazioni biochimiche. Industria Conserve, 71: 37-49.
33. Sigholt, T., U. Erikson, T. Rustad, S. Johansen, T. Nordtvedt, and A. Seland, 1997. Handling stress and storage temperature affect meat quality of farm-raised Atlantic salmon *Salmo salar*. Journal of Food Science, 62: 898-905.
34. Warriss, P.D., 1996. Instrumental Measurement of Colour. In Meat Quality and Meat Packaging. ECCEAMST, Utrecht, the Netherlands, pp: 463.