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Electrical Stunning of Edible Crabs

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Report

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Summary/recommendation:

In the project StunCrab, kindly supported by the Norwegian Research Council, SeaSide AS, Hitramat AS and Nofima has successfully developed and implemented electrical stunning of edible crab. The research has shown highest impedance for crabs in the region of 40-100 Hz, confirming 50 Hz as an adequate frequency. Crabs, however, have a high and size-dependent resistance. In order to stun the crab within 1 s, the direct exposure must be 220 V, 50 Hz AC, however, due to the high resistance, at least 10 s exposure is recommended. To ensure no revival the crab should be pre-chilled and kept in air or ice water after stunning. In a large scale test with 300 crabs placed in ice after stunning, no signs of conscience were observed before death.

Percentage loss of extremities (claws or feet) was relatively independent of voltage or exposure time, and typically 3-6% loss at 220 V. Due to the high contact resistance measured, effect of current is lost rapidly. To ensure good contact, spraying of the crabs with salt water prior to stunning and use of a conveyor belt to avoid single contact point between electrodes and crab, is recommended. IR camera revealed local heating, in particular in contact points of electrode with extremities. It is therefore recommended usage of a minimum current exposure time, 20 s maximum, and 10 s being optimum in most cases.

Summary/recommendation in Norwegian:

Gjennom støtte av Norges Forskningsråd til prosjekt: StunCrab har Nofima, SeaSide A/S og Hitramat A/S hatt som oppgave å utvikle og implementere elektrisk bedøvelse for taskekrabbe i slakteri. Dette har vært vellykket. Forundersøkelser viser at krabbe har høyest impedans i regionen 40–100 Hz noe som viser at 50 Hz er tilfredsstillende frekvens. Imidlertid har krabbe høy motstand som varierer med størrelse. For å kunne bedøve krabben innen 1 sekund må de eksponeres direkte for 220 V, 50 Hz AC. Imidlertid for å sikre en tilfredsstillende bedøvelse over tid må krabben eksponeres for minst 10 sekunder med strøm. Forsøk med avliving viser at dersom krabben bedøves med normal temperatur og plasseres i ferskvann vann, vil omtrent 40 % gjenopplive for så å dø av hypoksi. For å sikre død må krabbene enten kjøles på forhånd og lagres i luft eller plasseres i isvann eller direkte i isvann. Storskalaforsøk viser at av 300 krabber som ble plassert på is etter bedøvelse, vise ingen tegn til bevissthet frem til død.
På kvalitet viste resultatene at andelen kast av ben og klør var relativt uavhengig av voltstyrke og tid på henholdsvis 0 til 40 %. Også antallet ben kastet pr individ varierte, hvor det tenderte mot et ben ved høyere volstyrker og tid, mens lavere medførte kast av flere ben og klør. Det ble målt stor kontaktmotstand mellom krabbeskall og elektroden så effekt av strøm over tid vil synke raskt. For å sikre en god strømgjennomgang er det viktig at krabben sprayes med saltvann og er i bevegelse i elbedøveren slik at elektroden ikke ligger på samme posisjon. Storskala forsøk med elbedøver under optimale forhold viser at ved 220 V var andelen kastet ben lik forsøkene jevnt over 3–6 % kast. Forsøk med IR kamera viser at en får en betydelig lokal oppheting av krabben, spesielt om det er klør eller ben som har kontakt med elektroden. Det er derfor viktig at krabben utsettes for minimum med strøm som er i dette tilfelle ikke bør overstige 20 sekunder, hvor 10 ansees som optimal under alle forhold.

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1 Background

In recent years there has been an increasing focus on how to stun and kill aquatic animals such as farmed fish (EFSA 2004, 2009). Unlike invertebrates, the welfare for fish is regulated by law in most European countries. However a few countries like Norway have also regulated decapods and cephalopods into the same laws as they are animals that are considered to consciously feel pain and learn from it. This has been demonstrated on hermit crabs (Eldwood et al. 2009). Nevertheless decapods are usually killed and processed in traditional ways that involves live carving, boiling and asphyxia (Roth et al. 2010).

Decapods like the Edible crab are captured all along the south- and midwest cost of Norway. The carbs are delivered live to the few processing facilities that exist along the coast. At the processing facility the crabs are sorted into 2 main groups; boiled whole or carved into pieces for further processing. In the case of carving, the crabs are processed live by first splitting them into 2 parts, whereas the extremities are stripped off and the boiled. For the crabs that are to be boiled whole, the crabs are killed over night by using freshwater. This to assure that the crabs do not casts it extremities during boiling.

Previous reports on stunning and killing of edible crabs show that any attempt to kill or stun the crabs using gas or a thermal shock requires time before the crabs can be regarded as unconscious (Roth et al. 2009). Meanwhile this can, depending on method, inflict stress or pain jeopardizing the welfare of the animal even further, despite any good intentions. From that perspective electricity is promising, as edible crabs can be stunned unconscious within 1 s, using electric field strengths equivalent of 550 V/m in seawater (Roth et al. 2009). Lower field strength could result in failure to stun the animal followed and massive autonomy (Roth et al. 2009). Autonomy can also be reduced by prolonging the current duration, which also prolonged the unconscious condition. However any attempts to electrocute and kill the animal failed as 20 % of the edible crabs recovered within 1 h after being exposed to 3 min of electricity (Roth et al. 2009). These results clearly suggest that electrical can be used to stun the animal unconscious and not kill. The challenge is however to stun the animals at an industrial scale. Stunning them in seawater requires far too much energy, but recent development on fish uses dry stunning (Stansas, Seaside A/S, Norway), where the electricity is put directly through the animal getting in direct contact beween 2 electrodes. The principal of the drystrunner is that the fish are continuously transported on a conveyer belt acting as one electrode through a series of hanging metal plates acting as the other electrode. This principal could also be used for crabs.

The aim of this study was therefore to develop protocols for drystunning edible crabs and disseminate into commercial practice.

2 Material and Methods

In order to safely develop a commercial crab-stunner equivalent of 10 tons/h in capacity, the project was divided into 3 main phases. Phase 1 was to determine which electrical parameters that are optimum in dry stunning edible crabs based on the animals impedance and position. Phase 2 was to determine electrical setting required to stun the animal within 1 s and the duration required to prolong the unconscious condition until death.

Phase 3 was to develop a commercial stunner and test this under semi and full scale production. Phase 1 was carried out at Heløysund, Rogaland, while all other experiments were carried out at Hitramat AS, Sør Trøndelag.

2.1 Phase 1: Impedance related to frequency:

The experiment was conducted by taking one crab at the time and place them into a tank filled with seawater and killed with an overdose of Metacain (MS-222). This to ensure that the crab were lying still during measurements without physical damage. After all behavioral reflexes were lost the crab were immediately placed on a plate of stainless steel acting as one electrode, while the other plate electrode was placed onto the head (Figure 2). This to simulate the commercial condition in which crabs are electrical stunned using the Stansas#01™, (Seaside A/S, Stranda, Norway.) The electrodes were then connected with coaxial cables respectively to the high and low connection terminals on an Agilent 4294A Precision Impedance Analyzer (Agilent Technologies, Inc. USA). All measurements of impedance and phase angle for each fish was taken without changing position of the crab between the stunning shoe and stainless steel sheet. The impedance analyzer was programmed to scan over a logarithmic distributed frequency range from 40Hz to 1MHz and took measurements impedance and phase angle at 43 frequencies at 0.5V. To reduce the influence of noise the impedance analyzer was programmed to give an average value for each measured frequency, so the value of each of the 43 measured frequencies for each fish represent an average of 256 measurements.

All crabs where laying down on the electrode. To determine the importance of position, one crab was forced standing on all legs by placing a small piece of polystyrene underneath.

2.1.1 Impedance related to voltage

To look upon the changing characteristics of impedance related to voltage, the fish crab was after the impedance and phase angle measurement at 0.5V exposed to 50 Hz sinusoidal AC currents holding approximately 110 and 220V root mean square (RMS) output through a adjustable ring type transformer. Measurements of RMS values for ampere were done by using an ampere nippers connected to the oscilloscope and pinched on the wiring between the transformer and the stunning shoe. A laptop was used to record the measurements results received 20 MHz, FLUKE 123™ industrial scopemeter (Fluke Inc, Everett WA, USA) through a USB connection. For ampere at measurements 110 and 220V a FLUKE 80i-110s AC/DC current probe (Fluke Inc, Everett WA, USA) was used together with the scope-meter. On the PC FlukeView ScopeMeter Software for Windows SW90W (B. V. Tilburg, The Netherlands) was used to read the signal. A time relay was used to produce an example of connection current spices, signal acquisition was done by the previous mentioned scopemeter.

Impedance values for 50VAC and 50Hz was calculated from the recorded values of RMS voltage and ampere.

2.2 Phase 2: Stunning of edible crabs

To determine the electrical parameters required for stunning edible crabs, one crab at the time was placed in between the electrodes and exposed to 110-220 V 50 Hz AC for 1, 5 and 10 s of electricity. After stunning behavioral responses were recorded according to Roth et al. (2009) to determine the crabs conscious condition. Behavioral responses were focusing on the appendages/chelipeds, mouth, antennules and eyes, representing 2 behavioral responses from the posterior and anterior ganglion, receptively. All these behavioral responses were then summarized providing a score on consciousness at a scale from 0-8. To quantify death, the crabs were after stunning placed back to its environment and if the crab did not show any signs of recovery within the next 60 min, the crab was classed as dead.

2.3 Phase 3 Commercial stunning of edible crabs

For stunning edible crabs a STANSAS #01 was rebuilt and adjusted for edible crabs. This included an isolated ring transformer providing 0-220 V 50 HZ, AC. Several series of 1 cm wide electrodes was installed above the conveyer belt providing a mesh of electrodes always ensuring contact to the crab. Prior to contact between the electrodes a plastic plate was installed coning inwards pressing the crabs down onto the conveyer belt. Saltwater was sprayed over the crabs to reduce the contact resistance. During the experiment batches of hundred crabs at the time were evaluated. The crabs were prior to stunning either live chilled using –1 °C seawater for 30 min prior to stunning or used directly from the boat. The crabs where then exposed to 10-20 s of electricity and behavior and loss of appendages was evaluated. The crabs were then placed into fresh water, iceslurry or air. The crabs were then evaluated over the next hour to see proportion regaining consciousness. To see the effect of heating an IR video camera was placed in the end of the electrostunner.

3 Results and Discussion

As shown in Figure 1, the impedance (ohm) in edible crabs is dependent on the current frequency (P<0.0005, linear regression), with maximum effect in the region of 40-100 Hz. This clearly shows that the optimum stunning frequencies for crustaceans lays within net frequencies.

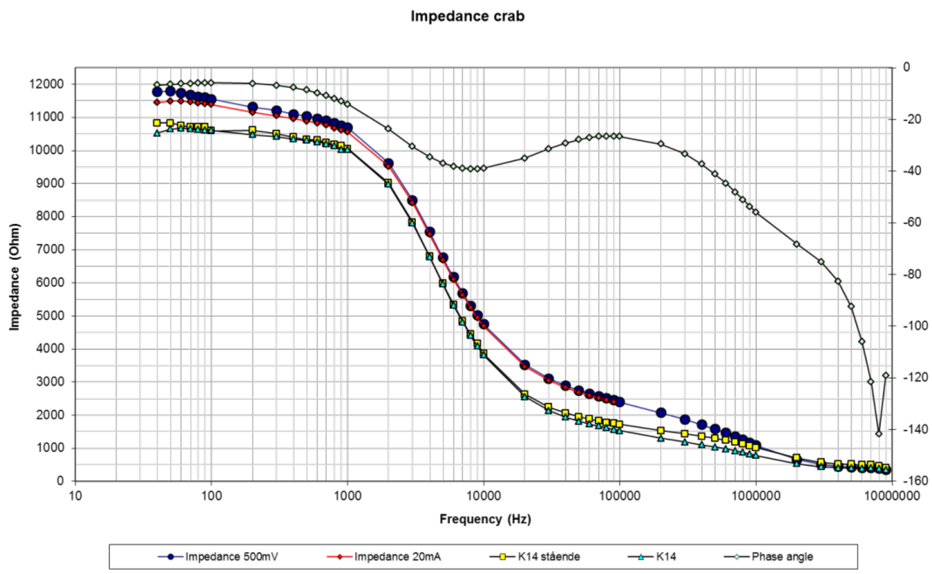

Figure 1 Impedance of edible crabs from 40-10 MHz. K14 represents the difference between an ediblecrab standing on its appendages versus laying down on a steel plate.

There were however differences amongst individuals variations between 15.5-10.1 kΩ at 50 Hz (Figure 3). This variation was positive correlated with the size of the crab measured as weight (r=0.64, P<0.05), but not the size of the carapace (P>0.22), indicating that the volume of the crab is of importance. Whether the crab is standing on its appendages during stunning or not is of little relevance as compared to individual differences.

The amperage flow during the first second of stunning using 220 V AC varied considerably from 0.65-2.2 amps between each crab.

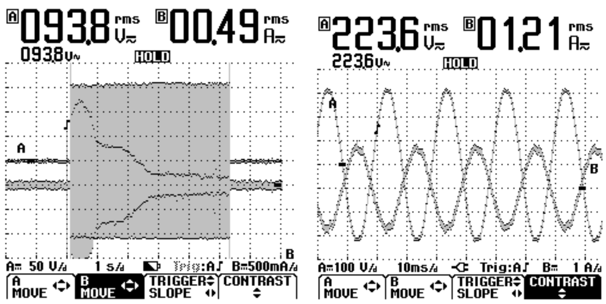

Figure 2 Ampere flow and frequencies

As shown in Figure 2 the amperage flow was parable against time, increasing rapidly the first 0.5 s before gradually decreasing over the next 5 s, indicating an increased contact resistance with heating. However due to the low conductivity of the carapace and the fact that crabs have high salinity inside, the animal acts as a condenser where we observed a 90 degree phaseangle between potential difference and the amperage (Figure 2)

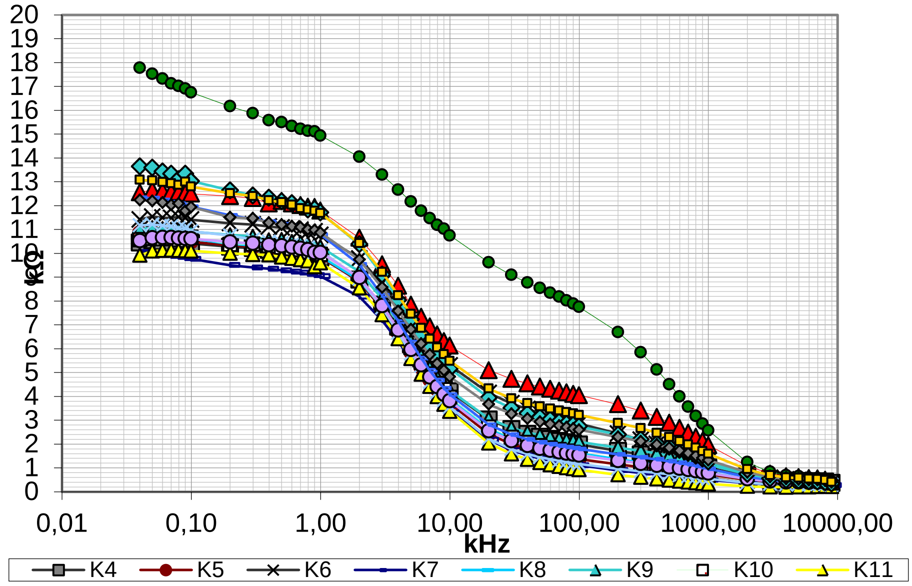

Figure 3 *Impedance of each single crab*

Newer regulations indicate that time before an animal should render unconscious is 0.5 s. Previous studies on mammals and fish show that 0.2 s is the time limit that can stun the animal (Cook et al. 1997 and Roth et al. 2003). It has been speculated that this is due to contact capacitance (Zivotofsky and Strous 2012). Results in figure 2 shows that the crabs actually acts as a large electric capacitor, explaining why the current required to stun the animal is almost 2 folds that what is reported for fish (Lamboiij et al. 2010), indicating that 1 s stun duration is probably on the boarder for a minimum stun duration.

3.1 Phase 2 stunning:

As shown in table 1 there was significant differences in behavioural score between crabs stunned at 110 V and 220 V, decreasing with the current duration (P<0.05). The difference in score between 110 and 220 V was mainly due to responses in the antennules and eyes, whereas differences was observed in the chelipeds, indicating that 110 V was not sufficient for stimulating the posterior ganglion. In this case it was difficult to evaluate the eyes as they became withdrawn into the carapace showing weak signs while moving them.

There were no significant difference in probability of autonomy between voltage and current duration. However as previous described there were noticed an increasing contact resistance causing amperage fall and burn marks indicating that the first second is important. Therefore a second trail was performed where one crab at the time was placed in an electrical stunner and exposed to electricity while moving through the system with several electrodes. Results show significant less autonomy explaining the importance of contact resistance. On behavioural responses crabs exposed to 1 s of electricity did within 1-2 minutes regain normal responses of the eyes and antennules, while responses of the chelipeds took up to 10 min. Increasing the current duration to 10 s prolonged time before recovery, but they all recovered although approximately 20 % never regained control of chelipeds.

Table 1 Results of electrical stunning

Voltage (v)	Current duration (s)	Behavioral Score (0-8)	No crabs casting chelipeds Probability autonomy	Tot. No. lost	n
110	10	2,9	0.11	14	35
220		0,2	0.2	11	35
110	5	3,1	0.4	4	10
220		0,3	0.0	0	12
110	1	3,9	0.4	5	10
220		0,6	0.25	3	12
220	10 moving	0.3	0.07	3	43

3.2 Phase 3 Commercial stunning of edible crabs

Commercial experiments show that electrical stunning was efficient is stunning large quanta of crabs under the circumstances that the slides singular through the system and not in big clusters. Live chilling prior to stunning could therefore be an alternative. Of the 400 crabs evaluated immediately after stunning using 220 V for 10 s, none were considered as conscious within in the minute before they were evaluated. Any attempts to reduce the voltage or current duration with the stunner failed to stun some animals properly. However the challenge is to kill the animal without the ability to recover in this process. After stunning the crabs were sorted by its meat content using a NiR (Qvision, Qvison AS, Norway). Live chilled crabs where then sorted into different 800 L tanks containing freshwater for intermediate storage. Examination of crabs show that they while heated up and as much as 30% had recovered within 1 h, dying of asphyxia. New sets of experiments were carried out, where live chilled and ambient crabs where stunned and stored into ice slurry. Close examination of 30 crabs from each group at intervals of 2 min over the next hour show that none of the crabs showed any signs of recovering. Large scale test of live chilled crabs stored into ice slurry show that none of the 271 crabs investigated showed any signs of life after 30 min and 1 h of storage. If the crabs are live chilled prior to stunning one possible solution is to store them in air under the circumstances that the air temperature is low. A total of live chilled 115 crabs placed in air were investigated, wheras non had recoverd within the hour. However instead of storing the crab before stunning, electrical stunning enables the factories to process the crabs directly, meaning that the crabs can be boiled or carved directly after stunning. This would be much faster and humane than any other attempts to kill them by asphyxia, which is a slow process with larger risks of recovering.

Results on autonomy show that approximately 7% of ambient crabs either lost one appendage or cheliped, while the number on live chilled crabs was 4 % in ($P>0.38$, $n=224$). Although electrical stunning causes som autonomy this number is in fact lower than otherwise would occur when handled and injuring each other.

Results on IR camra show that a 10 second current duration on a crab under constant movement does not head up. However if the crabs become stuck into the system, sliding local heating was observed especially on the appendages and chelipeds if they were in direct contact with the electrode. Therefore the current duration should always be limited to minimum 10 s of welfare reasons and 20 s for heating.

4 Conclusion

We conclude that electrical stunning is efficient in stunning the edible crabs at a commercial level. Minimum of electricity required for stunning the crabs within 1 s is 220V. The crabs should be exposed for a minimum of 10 s with electricity to ensure prolonged stunning and not exceed 20 s to avoid heating. The crabs should be processed immediately for killing and if not stored on ice or slurry to unsure that the animals remain unconscious until death. Autonomy was not avoided where approximately 4-7% lost one appendage.

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