Holding of Sea Urchins and Scallops in a RAS Transport System

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Report summary

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Ágrip á íslensku:	Tilraunir voru gerðar í að halda ígulkerum (*Strongylocentrotus droebachiensis*) og hörpudiski (*Chlamys islandica*) lifandi í RAS kerfi sem þróað var af Technion, Ísrael. Kerfið, sem hringdælir vatni, stýrir sýrustigi (pH) og fjarlægir skaðleg ammóníakssambönd, var sett upp í kæligámi til að halda hitastiginu við 4°C. Verkefnið var samstarf Technion, Ísrael og Matís og styrkt af EIT Food. Niðurstöður sýna lága dánartíðni ígulkera í RAS kerfinu við 4°C fyrstu geymsludagana, en dánartíðnin jókst síðan hratt; 80% ígulkera voru lifandi eftir átta daga, 50% eftir 12 daga og einungis 10% eftir 15 daga frá veiði. Ígulker sem geymd voru við 4°C á hefðbundinn máta við flutning á markaði (í polystyrene kössum) voru af svipuðum gæðum og ígulker úr RAS kerfinu, eftir fjögurra daga geymslu og hrognin voru enn neysluhæf eftir átta daga frá veiði. Öll ígulkerin í polystyrene kössunum voru hins vegar dauð 12 daga eftir veiði og hrognin óneysluhæf. Hörpudiskur lifði vel í RAS kerfinu; eftir 24 daga geymslu var enn um 89% af hörpudiskinum lifandi við 4°C.		
Lykilorð á íslensku:	*Ígulker, hörpudiskur, RAS kerfi, flutningur á lifandi dýrum, gæðamat*		

Summary in English:	Trials were carried out at Matís on holding live sea urchins and scallops in a RAS system developed by Technion, Israel, which not only recirculates the water, but additionally controls the pH and removes toxic ammonia. The aim of the trials was to test the feasibility of holding sea urchins and scallops alive in the RAS system for 10 days at 4°C, with at least 90% survival. The project was funded by EIT food, and the participants were Technion and Matís. The survival of sea urchins held in the RAS system at 4°C was high during the first five days. Eight days from catch the survival was only 80%, after 12 days about 50% and after 15 days, 10%. Sea urchins, packed in the standard way of transporting live urchins (in polystyrene boxes at 4°C) were at similar quality as the RAS stored sea urchins, five days from catch and the roe was still edible at eight days from catch. All the urchins in the polystyrene boxes were dead after 12 days storage and the roe inedible. Scallops had a high survival when held in the RAS system or about 89% after 24-days at 4°C.
English keywords:	*Sea Urchin, Scallops, RAS system, live transport and storage, quality*

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1. Introduction

During the period October until December 2019, trials were carried out at Matís on holding live sea urchins and scallops in a RAS storage and transport system. The idea behind the trials was to simulate holding and transport of live sea urchins and scallops from Iceland to potential markets in Europe and Asia.

Already, Iceland is a leading supplier of live sea urchins to markets in Europe, mainly to France (Stefansson *et al*., 2017). The current transport mode of live sea urchins is relatively simple; they are packed "dry" in polystyrene (EPS) boxes with ice mats on top and bottom and shipped by air. The urchins are believed to be "alive" or at least to be in good condition for consumption, for about 7 days at 3-4°C. In a recent report on holding live sea urchin in EPS boxes at 3-4°C it was concluded that they could be expected to be alive for 5-9 days based on whether their mouth was open or closed (Stefánsson and Ólafsdóttir, 2017). James *et al*., (2017) concluded, that sea urchins could be held alive and in good condition in polystyrene boxes for 14-44 hours depending on temperature.

Holding and shipping of sea urchins in recirculating sea water may open options on keeping them alive for long periods especially if ammonia stripping is carried out. Still, such transport is challenging, expensive and difficult, due to factors such as oxygen supply, increase of carbon dioxide in the water, accumulation of toxic ammonia and changes in pH.

In our trials we used a RAS holding and transport system developed by Technion, Israel Institute of Technology and BioFishency (www.biofishency.com) which not only recirculates the water, but additionally controls the pH and removes toxic ammonia. The system was set up in a 40 foot reefer container to control the temperature and was connected to two 1 m^3 fish tanks. The aim of the trials was to test the feasibility of holding sea urchins and scallops alive in the RAS system for 10 days at 4°C, with at least 90% survival. The project was funded by EIT food, with Technion leading and Matís participating.

2. Materials and methods

2.1 Experimental plan

The green sea urchins (*Strongylocentrotus droebachiensis*) were caught in the Breidafjordur area in Iceland. For the first trial, the urchins were caught on the 29th of October 2019 by Fjóla SH 7, using a modified dredge. The second batch of sea urchins were caught on the 13th of November 2019 by Sjöfn SH 707, using a modified dredge. Both boats are operated by Thórishólmi (Stykkishólmur, Iceland).

Figure 1. The dredge used for catching urchin and newly caught urchin in a fish tub.

Thórishólmi is the largest exporter of live sea urchin from Iceland and is one of the leading suppliers of live urchins in Europe. Breidafjordur, to the west of Iceland, is known for urchins of good quality, meaning urchins with a high gonad content or at least 10-12%.

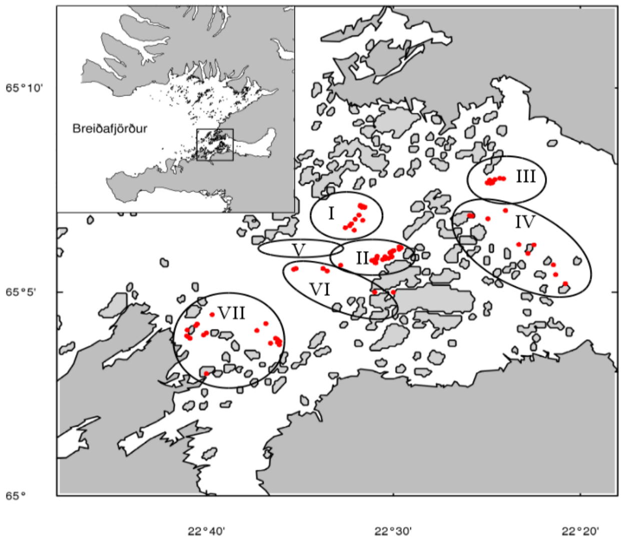

Figure 2. Breidafjordur, the fishing area for the urchins and scallops used in the trials.

On landing, the urchins were sorted; those in good condition for export were rinsed in seawater and the whole live animals packed into polystyrene boxes (EPS), 3 kg of urchins per box, with ice mats on top and in the bottom of each of the boxes – the same method as used for regular export from Iceland. The urchins were then loaded into a chilled truck (0-4°C) and sent to Matís, Reykjavík, a journey that took 24 hours.

Figure 3. Sea urchin in EPS boxes on arrival to Matís.

The first shipment of urchins (10 EPS boxes; in total 30 kg of urchin) arrived at MARS (the aquaculture site of Matís) on the 30th of October, and the second batch on the 14th of November (16 boxes; 48 kg of urchin). On arrival, the sea urchins were arranged into baskets (60 x 40 x 20 mm); 24 urchins per basket in the first trial and 30 urchins per baskets in the second trial. The baskets were closed with a lid and placed in the RAS system. In both trials, urchins were packed or arranged into eight baskets.

Figure 4. Sea urchin arranged into baskets and closed with a lid to avoid the urchins to escape.

In the first trial (a pre-trial), dead urchins were removed from the trays at day three from catch and again on the first sampling day (day 5 from catch); only live urchins were used for the evaluation. The final sampling was carried out on day 12 from catch.

In the second trial, urchins kept in EPS boxes were used as a control (group CONTROL) for comparison with the urchins held in the RAS system (group TANK). The control group was stored in the reefer (set at 4°C) and thus kept at the same temperature as the TANK urchin. It should be noted that the CONTROL urchins were packed by the supplier in the same manner as urchins for export (in EPS boxes with ice mats). Sampling of sea urchins in the second trial was carried out on day one from catch (only from group CONTROL) and then on day five, eight, twelve and fifteen from catch.

The scallops (*Chlamys islandica*) were caught in Breidafjordur on the 13th of November, by Sjöfn SH 707, using a modified dredge. On landing, the scallops were packed in mesh bags and then into three kg EPS boxes with ice mats on top and bottom. The boxes were loaded on a chilled truck (0-4°C) and delivered to Matís on the 14th of November. In total, we received 16 boxes of urchins and four boxes of scallops (Trial 2).

On arrival at MARS, the scallops were arranged into baskets (60 x 40 x 20 mm), approximately 27-29 scallops per tray. In total, four baskets of scallops for the trial. The trays were then placed into the 1 m^3 tanks connected to the RAS system.

Figure 5. Scallops on arrival in EPS boxes and after arranging in trays.

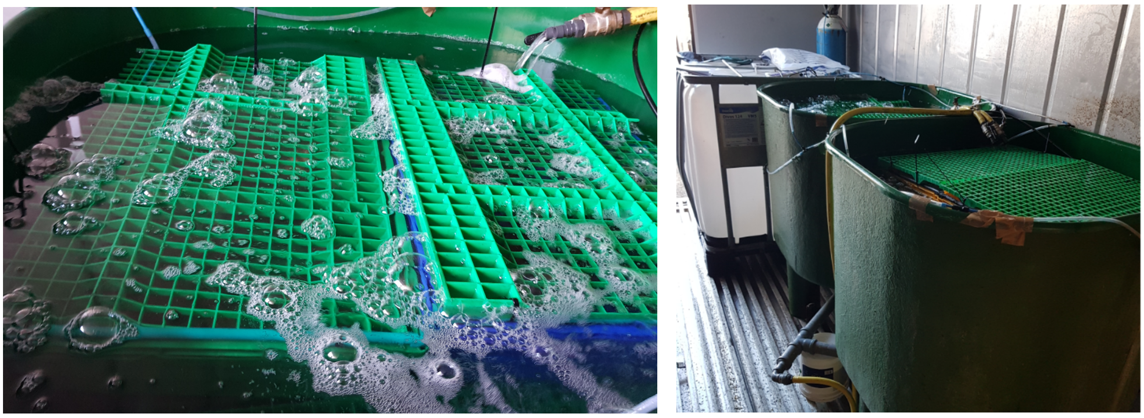

Figure 6. Sea urchin and scallops in the RAS system (Trial 2).

The scallops were kept in the RAS system with the sea urchins in *Trial two*. The scallops were sampled initially to evaluate their quality (two days after catch) and again from the RAS system after six days of storage. The survival of the scallops was recorded regularly to estimate mortality. The last quality evaluation was set at day 27 from catch, but the night before sampling, a malfunction occurred in the RAS system, all the scallops died and thus they were not evaluated.

Figure 7. Left: Sea urchin checked in the RAS system, right: staff and setup of tanks.

2.2 Quality evaluation methods

The following methods were used for the evaluation of sea urchins: Estimation of survival, sensory analysis using GDA (Generic Descriptive Analysis), cooking yield, standardised photo shooting, pH measurements, roe ratio and proximate analysis (moisture, protein, fat, ash and salt content).

The following methods were used for the evaluation of scallops: Estimation of survival, sensory evaluation using product analysis, and proximate analysis (moisture, protein, fat, ash and salt content).

2.2.1 Estimation of survival

Sea urchins: At each sampling point for group TANK (*Trial two*), an attempt was made in evaluating whether the sea urchins were alive or dead. This is somewhat a difficult task since the urchins are not very mobile animals, especially when out of water. The urchins were obviously alive if some movement was seen in the spines. They were considered dead, if no movement of spines was detected. Only live urchins were used for sensory evaluation, to ensure that the products were of good quality for the panellists, and the same urchins were used for other evaluations. No attempt was made to count live or dead sea urchin in the CONTROL group, since the producer guarantees the product quality under the conditions used in this experiment for seven days (at 4°C).

Scallops: Scallops were considered dead if they were open and would not close when pressed or taken out of the water.

2.2.2 Photos of sea urchins

Photos were taken of all sea urchins used for analysis, dorsal and ventral side, and their roe. A portable photo booth was used to provide a standardized lighting so all photos of sea urchins and roe, during the trials, could be compared.

2.2.3 Roe ratio

Roe ratio for each sea urchin was calculated using the weight of the freshly removed, unwashed roe, divided by total weight of the sea urchin.

2.2.4 Proximate composition

Moisture content: The water content was determined by the difference in weight of homogenized muscle samples before and after drying for 4 h at 102 to 104 °C (ISO 1999). Results were calculated as g water per 100 g muscle.

Salt content: The salt was determined by the method of Volhard according to the AOAC Official Methods of Analysis (1995).

Protein content of the roe/scallops was estimated by the Kjeldahl method (ISO 1997) with the aid of a Digestion System 40 (Tecator AB, Hoganas, Sweden) and calculated using total nitrogen (N) x 6.25.

Total lipids of the samples were extracted according to the method of Bligh and Dyer (1959). The lipid content was determined gravimetrically. The results were expressed as g lipid per 100 g of the sample.

2.2.5 pH

The pH of sea urchin roe was determined using a pH meter with a glass electrode (Knick, Berlin, Germany) by inserting the electrode directly into the minced roe.

2.2.6 Sensory evaluation

GDA – Generic Descriptive Analysis

The sensory method, Generic Descriptive Analysis (GDA, Lawless and Heymann, 2010) was used to analyse samples of sea urchin roe. Nine panellists participated in the sensory evaluation. All panellists had been trained according to international standards (ISO, 2014); including, in the detection and recognition of tastes and odours, use of scales and in the development and use of descriptors. The members of the panel were experienced in using the GDA method. The intensity of each attribute for a given sample was evaluated using a 15 cm unstructured scale which in analysis was transformed to numbers from 0 to 100. All attributes were defined and described by the sensory panel during earlier projects. The sensory attributes were 10 and are described in Table 1. Two training sessions were carried out prior to the analysis in order to harmonise the panellists´ use of the attribute scale.

For the GDA, 12 to 40 sea urchins were used for each sample group per sampling day. First, each sea urchin was opened with a knife. Second, the roe was removed from the urchin, weighted and then rinsed with water containing 3% NaCl. Each sample consisted of one or two strips of roe from one sea urchin, placed in a small white plastic bowl with a lid, coded with a three-digit random number. Each panellist evaluated quadruplicates of each sample group in a random order (four samples per session). A computerised system (FIZZ, Version 2.51C, 1994-2018, Biosystémes) was used for data recording.

Product evaluation

Four panellists described the odour, appearance, flavour and texture of the scallops, first individually and then the panel discussed the results and reached a consensus on the description of the sensory characteristics.

2.2.7 Total plate counts (TPC)

Total plate counts were determined on the recirculating water in the RAS system by a conventional "pour-plate" method on Plate Count Agar. Incubation temperature was at 22°C (72 hours) for psychrotrophic bacteria (NMKL 184, 2006).

2.3 Other analysis

Analysis on pH, alkalinity, total ammonia nitrogen (TAN), oxygen saturation and temperature in the recirculating seawater were carried out and are covered in a separate report prepared by Technion, Israel institute of Technology.

2.4 Data analysis

In *Trial two* (sea urchins) a comparison was carried out on the sensory data (GDA – Generic descriptive analysis) between TANK roe and CONTROL roe separately on day five and eight from catch. Analysis of variance (ANOVA, General linear model method) was used for these comparisons, correcting for difference in panellists´ use of the scale. One Way ANOVA was used to analyse changes in TANK roe during the storage time. Since the attribute “colour” is categorical, a Chi-Squared test was used for analysis of colour difference between TANK roe and CONTROL roe on days five and eight from catch. The sensory evaluation program Panelcheck V1.3.2 (Nofima, Tromsø, Norway) was used to assess panel performance. The program NCSS 2000 (NCSS, Utah, USA) was used for statistical analysis of the results. Duncan´s test was used to perform multiple comparisons between groups. The significance level was set at 5%.

Table 1. Sensory attributes for sea urchin, scale anchors, and definitions.

Sensory attribute	Scale	Definition
sea odour	none || much	very fresh fish, seashore, skin of fresh salmon, cucumber
white precipitations	none || much	white precipitations in roe
colour	yellow/ orange/ red/ brown	colour of roe
strength of colour	light || dark	strength of colour
sweet flavour	none || much	sweet flavour
sea flavour	none || much	sea flavour
bitter flavour	none || much	bitter flavour
egg yolk flavour	none || much	egg yolk flavour, raw egg yolks
softness	none || much	much: whipped cream, pudding, cake icing

3. Results and discussion

3.1 Trial one – sea urchins

Of the 192 urchins, placed initially in the RAS system, 37 (19%) had died three days from catch and in total 70 (36%) on day five from catch. All the sea urchins were dead after twelve days from catch in the RAS tanks and were for this reason, not evaluated. The salt content of the recirculating water was found to be low or 2,6% and the bacteria growth was also quite high initially in the system or log 4.9 CFU/ml; possibly these two factors may have affected the mortality rate of the urchins. It should also be kept in mind that the way the sea urchins were caught, handled and transported, is likely a stress factor. It has been observed in roe enhancement trials at Matís, that the mortality rate is the highest during the first five days from catch and up to 20-40% of sea urchins may be expected to die within two weeks storage in feeding tanks (Stephen Knobloch, personal communication).

3.2 Trial two – sea urchins and roe

3.2.1 Estimation of survival

At each sampling point an attempt was made to evaluate whether the sea urchins were alive or dead for the TANK group. The mortality was low on day five but after that an increasing mortality rate was observed. On day fifteen only 10% of the urchin were alive (Figure 8).

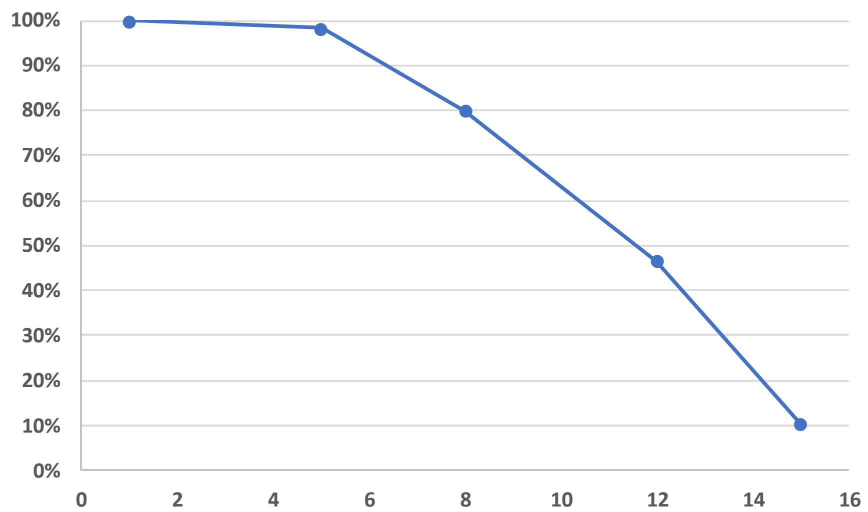

Figure 8. Percentage of live sea urchins (group TANK) in the RAS system with time (Trial 2). X-axis: Storage time (days), y-axis: Percentage of live urchin

James and Evensen (2018) point out that it is possible that a sea urchin exposed to adverse conditions will suffer delayed mortality for up to two weeks. Sea urchins transported by air could be alive on delivery at a processing facility, but may be unlikely to survive re-immersion in seawater (e.g. for subsequent roe enhancement). An average survival for sea urchins intended for roe enhancement –

that is two-week post transport – was found to be 62.8% (James *et al*., 2017). The survival ranged from 42% to 93% in 10 crates. The survival of sea urchins out of water has been shown to be temperature dependant, highest survival at low temperatures (3-4°C); further, even when held at low temperature the survival of sea urchins is time-dependant (James *et al*., 2017). Green sea urchins – from a test site – have been shown to survive in aerated transport site for up to 22 days at 4-5°C (James *et al.,* 2017).

In our trial, we used an aerated RAS system and additionally kept the accumulated ammonia at low levels. Still, we only observed a 80% survival of sea urchins eight days from catch, and 10% 15 days from catch. This was lower survival than the aim of the trials and the needs of the urchin supplier; at least 90% survival of sea urchins is required after holding them for 10 days at 4°C, in a recirculating sea water system. As we did not acclimatise the sea urchins before starting the trial, we find it likely that the stress factors due to catch, handling and transporting affected the survival.

3.2.2 Appearance of sea urchins and roe

The changes in appearance of "live" sea urchins during the storage period can be seen in photos 9-13. The appearance of the urchins is good, shortly after catch (day one from catch; Figure 9), with most spines intact on the urchins and movement of spines.

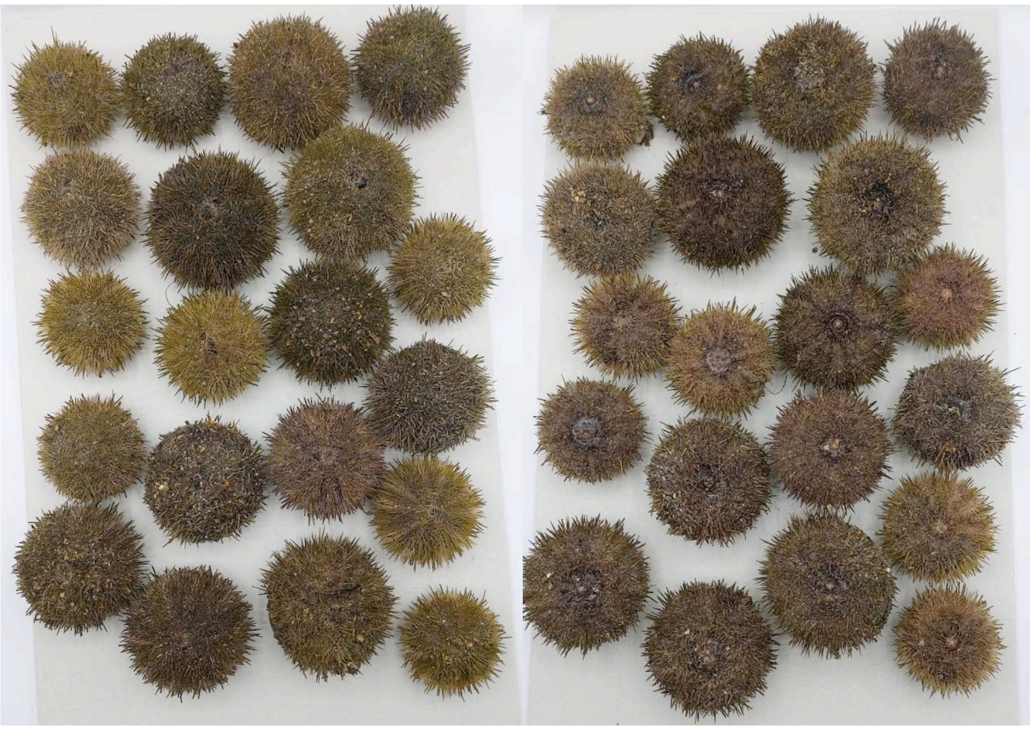

Figure 9. Sea urchins one day from catch (CONTROL), left: dorsal side, right: ventral side.

Five days from catch the urchin from CONTROL and TANK groups looked similar to that of urchins from day one (Figure 10); still, some had started to lose spines on the ventral side. Differences in appearance were observed between the CONTROL and the TANK urchins, as the CONTROL ones were somewhat darker, and the spines were looser than that of sea urchins stored in the RAS system (Figure 10).

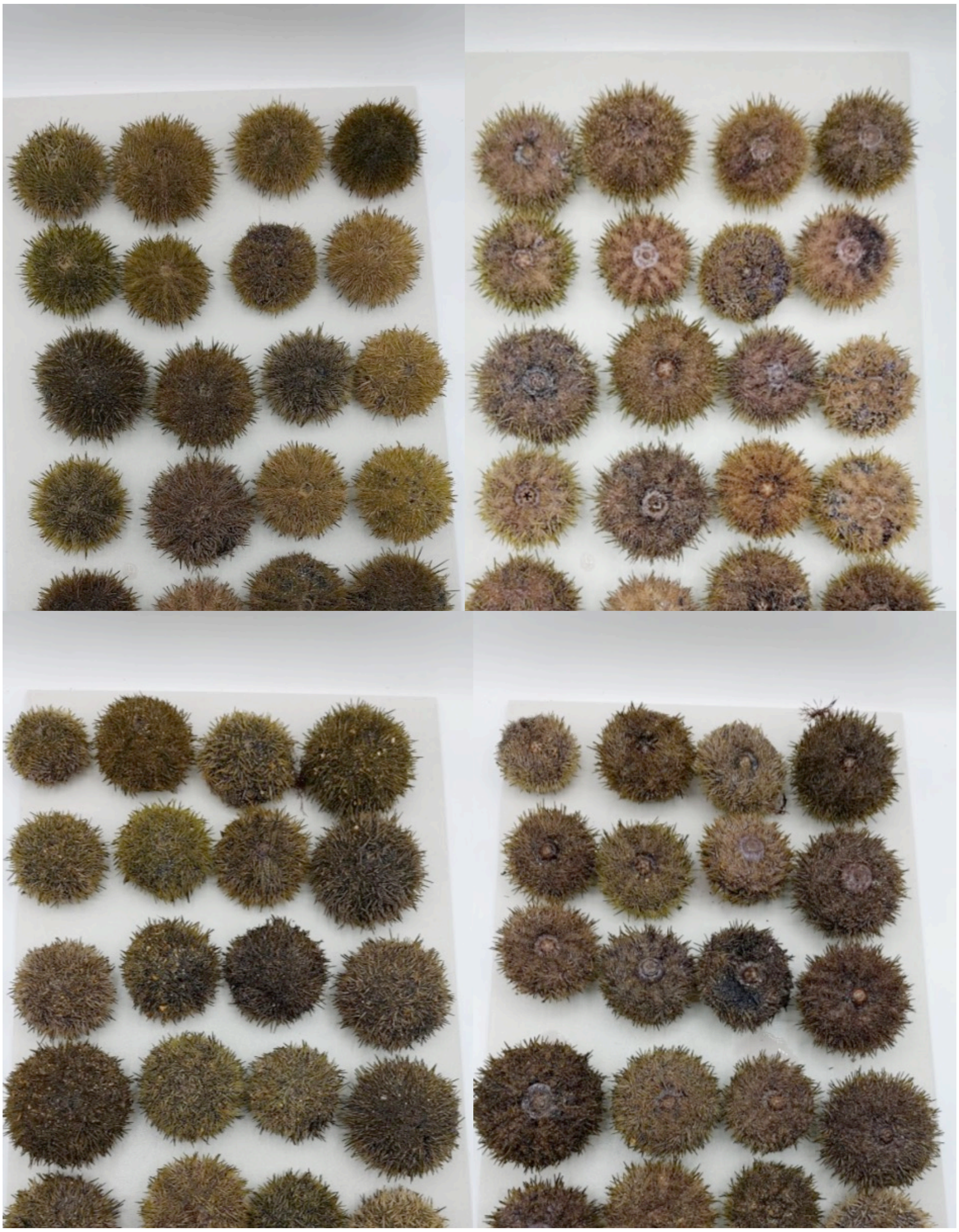

Figure 10. Sea urchin on day 5. Upper: TANK group, lower: CONTROL group. Left: dorsal side, right: ventral side.

On day eight, live sea urchins from the TANK still looked like those from day one from catch; the spines were intact, and the colour was light and green (Figure 11). The appearance of the CONTROL sea urchins was however very different to that of freshly caught urchins; many had lost their spines, and most had become dark and the odour in the boxes was not fresh (Figure 11).

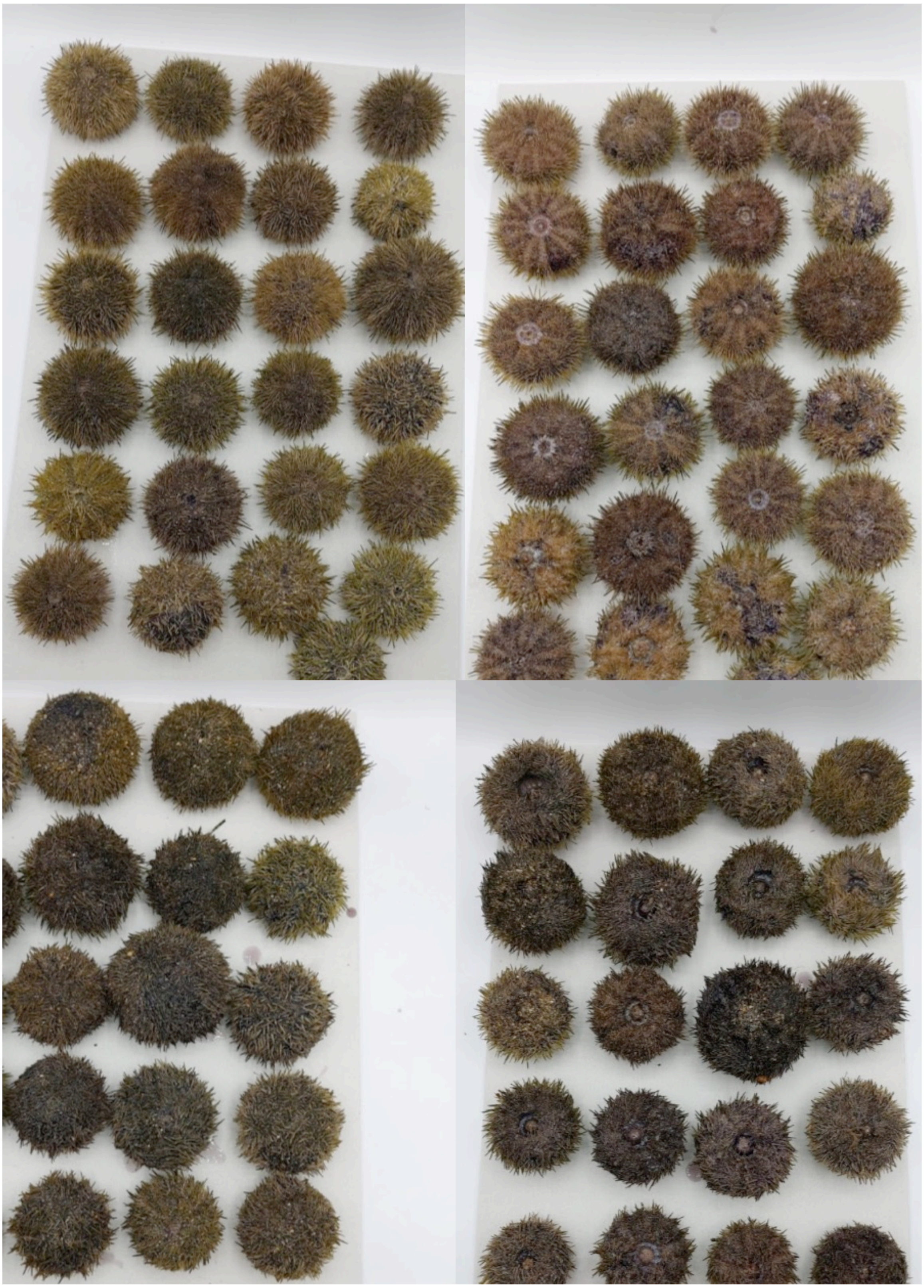

Figure 11. Sea urchin on day 8. Upper: TANK group, lower: CONTROL group. Left: dorsal side, right: ventral side.

On day twelve from catch (Figure 12) large differences were seen between the dead and live sea urchins from the TANK. The alive looked good, light in colour and with intact spines, whereas the dead had completely lost their spines and had become grey and/or dark (Figure 12).

Figure 12. Sea urchin on day 12, TANK group. Upper: live sea urchin, lower: dead sea urchin. Left: dorsal side, right: ventral side.

On day fifteen, the few sea urchins that remained alive had started to lose their spines and were somewhat darker in colour (Figure 13).

Figure 13. Sea urchin on day 15, TANK group, live sea urchin. Left: dorsal side, right: ventral side.

Photos of the sea urchin roe during the storage period can be seen in Figures 14-18. No clear changes in the appearance of the roe was observed with storage time, with one exception; contamination, probably from gut, seen as small dark grains or balls, decreased during the storage time and was minor on days twelve and fifteen from catch (Figures 17 and 18). Some differences were observed between roe from TANK and CONTROL groups on day eight from catch, when more roe from urchin stored in the CONTROL (EPS boxes) had a dark liquid and some were slightly dissolved (Figure 16).

Figure 14. Sea urchin roe one day from catch.

Figure 15. Sea urchin roe five days from catch. Left: TANK group, right: CONTROL group.

Figure 16. Sea urchin roe eight days from catch. Left: TANK group, right: CONTROL group.

Figure 17. Sea urchin roe 12 days from catch, TANK group.

Figure 18. Sea urchin 15 days from catch, TANK group.

3.2.3 Roe ratio

Roe ratio was high in the sea urchins and did not decrease with storage time (Table 2). In fact, the roe ratio appeared to increase slightly with storage time in the TANK sea urchins (Figure 19).

Table 2. Roe ratio from sea urchin during the storage time. Different letters indicate a significant difference between the relevant groups.

Day	Storage		Roe ratio	No of urchin
one				
	FRESH	**c**	22%	40
five				
	EPS	**bc**	26%	40
	TANK	**c**	23%	40
eight				
	EPS	**bc**	25%	40
	TANK	**a**	31%	25
twelve				
	TANK	**ab**	29%	14
Fifteen				
	TANK	**ab**	29%	12

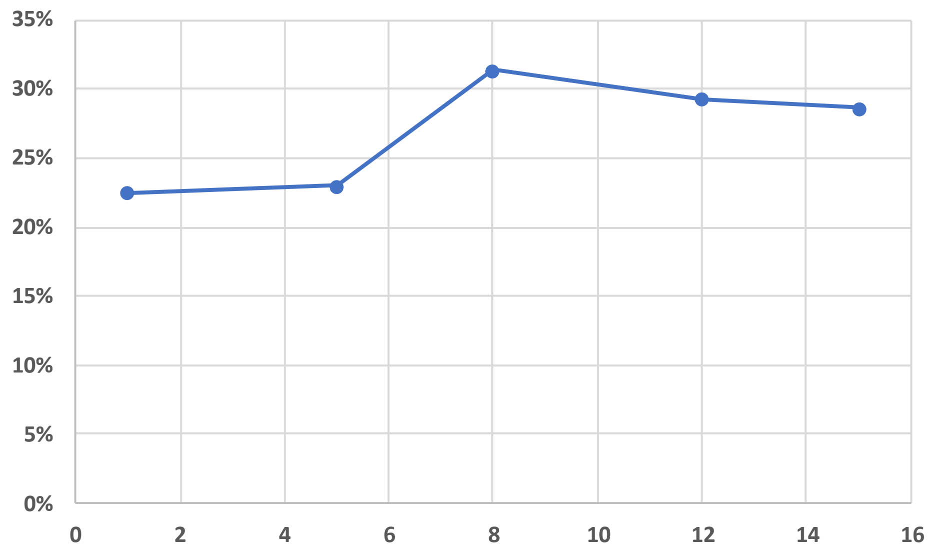

Figure 19. Roe ratio from sea urchins from group TANK with storage time. X-axis: storage time in days. Y-axis: roe ratio.

3.2.4 Proximate composition

The average values for proximate composition of sea urchin roe were 14,3% protein; 74,6% water; 4,1% fat; and 2,2% ash (Table 3). The composition of the roe from sea urchins stored in the RAS tanks and in the EPS boxes appeared to be very stable during the storage time. The pH in the roe varied between 6.05 and 6.2.

Table 3. Proximate composition of the sea urchins

Day	Storage	Protein	Water	Fat	Ash	pH
one						
	TANK	14%	76%	4%	2%	
five						
	TANK	15%	74%	4%	2%	
	EPS	15%	75%	4%	2%	
eight						
	TANK	15%	73%	4%	2%	6,05
	EPS	14%	74%	4%	2%	
twelve						
	TANK	15%	73%	4%	2%	6,2
fifteen						
	TANK	12%	77%	4%	2%	6,2

3.2.5 Sensory evaluation

The results from GDA are shown in Table 4. In general, the sea urchin roe was characterised by a moderately strong sea odour, rather strong sea flavour, moderately strong sweet flavour and egg yolk flavour, and slightly bitter flavour. White precipitations were seen in some of the roe and the texture was very soft. However, large differences were observed between roe from different individuals. In general, minor differences were observed between the two groups, TANK and CONTROL, five and eight days from catch. The CONTROL group had stronger sea odour five days from catch and more white precipitations. Less colour strength was detected for the TANK group compared with the CONTROL eight days from catch. Comments from the panellists indicate a clear difference between the groups, with samples from the CONTROL group having an off-odour and off-flavour, described as iodine, chemical, mouldy or sewage. Also, many samples from the CONTROL group were not tasted on day eight from catch due to off odour.

Table 4. Mean values for GDA sensory attributes for sea urchin roe during the storage time in days (D). P-values are shown for comparison between TANK roe (TA) and CONTROL roe (CR) on storage days 5 (D5) and eight (D8).

sensory attribute	D1	D5_TANK	D5_CONT	p-value	D8_TA	D8_CR	p-value	D12_TA	D15_CR
sea odour	38	29	48	0,049	30	27	0,702	29	31
white precipitations	18	15	13	0,537	18	8	0,021	25	8
strength of colour	59	56	56	0,972	46	59	0,006	43	49
sweet flavour	41	40	38	0,523	51	42	0,181	39	29
sea flavour	57	50	54	0,494	37	24	0,216	54	51
bitter flavour	24	18	18	0,972	6	13	0,396	10	9
egg yolk flavour	46	37	41	0,112	57	54	0,203	44	39
softness	66	71	72	0,739	65	66	0,558	74	74

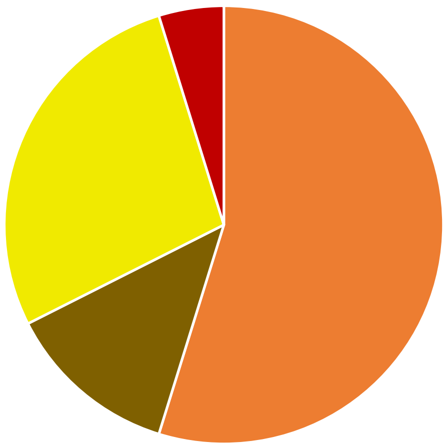

Figure 20. Average colour distribution among the sea urchin roe (Trial 2).

3.2.6 Total plate counts

Figure 21 shows the total aerobic growth in the recirculating seawater during the trials. The microbial counts were high at the start of *Trial one* and remained higher at all sampling time than that of *Trial 2*. The counts remained low in *Trial 2* from day six from catch and onwards.

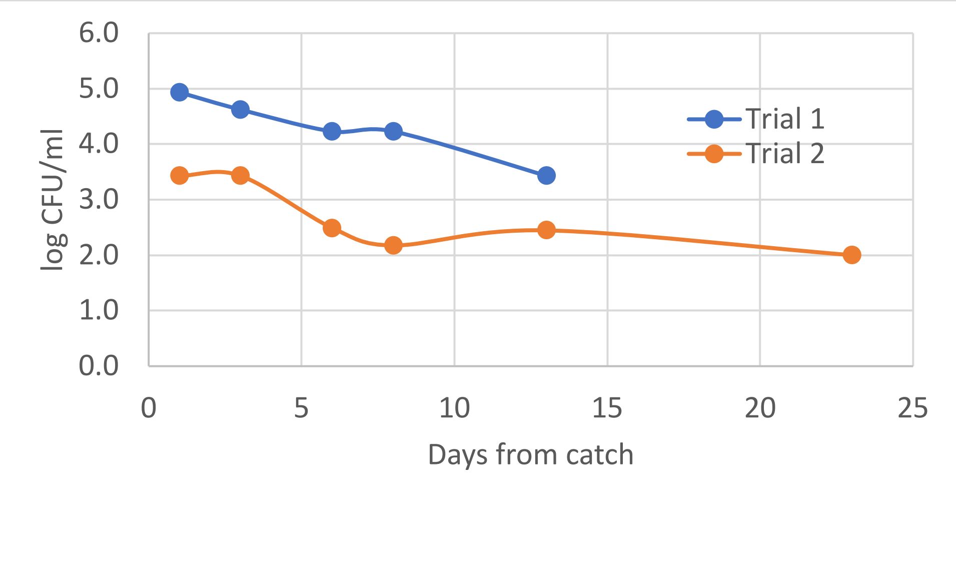

Figure 21. Total Aerobic Count in the RAS system for the sea urchins and scallop trials.

3.3 Scallops

The scallops thrived well in the RAS system; all (112 of 112 scallops) were alive at the first sampling date (six days from catch). On days 12 and 20 from catch, 80 of 83 scallops (96%) were still alive and 74 of 83 (89%) on day 24 from catch. Unfortunately, the RAS system broke down on day 27 from catch and all the scallops died.

The protein content was 19% in the scallops, water 75-76%, fat 0.2% and ash 1.6-1.7%.

Sensory characteristics of the scallops were normal, both when evaluated after two days of storage in EPS boxes, and after storing for six days in the RAS system. The odour reminded panellists of shellfish and lobster, and the flavour was sweet, metallic and fresh. Most of the scallops were very light in colour, but some had a slightly darker hue. The texture was firm at first bite, tender and slightly rubbery. After six storage days, all the scallops were alive and very lively, even more than that when evaluated after two storage days in EPS boxes.

4. Conclusion

The survival of sea urchins held in a RAS system at 4°C where toxic ammonia was removed, was high during the first five days. Still, the survival was only 80% eight days from catch, about 50% 12 days from catch and 10% 15 days from catch. Sea urchins at 4°C, packed dry in the standard way of transporting live urchins (polystyrene boxes) were at similar quality as the RAS stored sea urchins, five days from catch and the roe was still edible at eight days from catch. However, all the urchins in the polystyrene boxes were dead after 12 days and the roe inedible. Roe quality of live sea urchins did not decrease with storage time in the RAS system. The roe ratio remained high during the 15 days storage period or from 23-31%, the proximate composition was stable and no or minor changes were seen in sensory characteristics. Less contamination, probably from gut content, was seen in roe stored for twelve and fifteen days in the RAS system. Less off-odour and off-flavour was detected in roe from urchin kept in the RAS system than in those kept dry in polystyrene boxes after five and eight days of storage. The urchins from the RAS system also looked healthier, lighter in colour, more active and with intact spines.

Overall, the survival of the green sea urchins was lower than our aim of at least 90% survival in the RAS system during a 10-day holding period at 4°C. Still, it may be feasible to use a RAS system, where accumulated ammonia is removed, to hold and transport live sea urchins, but more research is needed to optimise the survival in view of the current means of catching and handling the animals. Acclimation of sea urchins to the storage conditions in the RAS system for seven and up to 14 days may be necessary to improve survival, before transport from one location to another is possible.

Scallops had a high survival when held in the RAS system or about 89% after 24-days at 4°C. Holding and transporting of scallops in the RAS system may be promising, but further research is needed to optimise the storage conditions.

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