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Icelandic Fisheries Laboratories Report Summary

Title / titill:	**Redfish Colour - Processing Improvements on Board Freezing Trawlers**		
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Summary in English:

Redfish (*Sebastes mentella*) and orange redfish (*Sebastes marinus)* were treated with sodium erythrobate (SE) to preserve the red skin colour. The fish was treated at different processing stages on board of a freezing trawler. The purpose was to evaluate the effect of processing on the skin colour during frozen storage and thawing. Conventional processing line for whole frozen redfish is as following:
Heading- Dipping (1% SE)- Grading- Packaging- Freezing- Glazing- Frozen storage.

Skin colour was measured before freezing and during one year of frozen storage. The colour was measured in seven treatment groups of redfish and orange redfish, using the CIE L*a*b* scale. The redfish groups were; conventional processing, no SE dipping during processing, two hours delay before processing, two hours delay on ice before processing and SE in the glazing water. The orange redfish treatment groups were; conventional processing and SE in the glazing water. Most fade of red colour occurred during processing or shortly after freezing. Sodium erythrobate treatment did not stop the discoloration, but hindered it considerably, before and during frozen storage as well as during prolonged thawing. Glazing with sodium erythrobate was beneficial during frozen storage, though more in redfish than orange redfish and stabilised colour change during thawing especially with the orange redfish.

English keywords: Redfish, skin colour, frozen storage, sodium erythrobate.

Ágrip á íslensku:

Djúpkarfi (*Sebastes mentella)* og gullkarfi (*Sebastes marinus*) var baðaður með natríum erythrobate (iso-askorbat, kallað erybat) til þess að varðveita rauða lit roðsins. Fiskurinn var meðhöndlaður og baðaður á mismunandi stöðum í vinnslulínu fyrir heilfrystan karfa um borð í frystitogara. Tilgangurinn var að meta áhrif vinnslunnar á roðlit karfa í frystigeymslu og þíðingu með það að markmiði að viðhalda betri rauðum lit á karfa en hingað til hefur tekist. Vinnsluferli fyrir heilfystan karfa um borð í togara er með eftirfarandi hætti:
Hausun- Böðun (1% erybat)- Flokkun- Pökkun- Frysting- Íshúðun- Frystigeymsla.

Fylgst var með roðlit karfa fyrir og eftir frystingu og í frystigeymslu í allt að eitt ár. Liturinn var mældur á sjö tilraunahópum karfa með litarmæli í CIE L*a*b* mælihætti. Fimm tilraunahópar voru af djúpkarfa; viðmiðun með hefðbundinni vinnslu, erybat böðun sleppt, tveggja tíma bið fyrir vinnslu, tveggja tíma bið á ís fyrir vinnslu og erybat í íshúðunarvatni, auk tveggja hópa af gullkarfa; viðmiðun með hefðbundinni vinnslu og erybat í íshúðunarvatni. Helstu niðurstöður voru að mesta litarbreytingin á frystitímanum átti sér stað fljótlega eftir frystingu. Tafarlaus böðun á karfa með erybati leiddi í ljós minna litartap í samanburði við biðtíma fyrir böðun eða enga böðun. Tafarlaus böðun á karfa með erybati og erybat í íshúð gáfu hæstu einkunn fyrir rauðan lit allan frystitímann og erybat í íshúðunarvatni skilaði bestum árangri við langan þíðingartíma.

Lykilorð á íslensku: Karfi, roðlitur, frystigeymsla, erybat (ísó-askorbat).

CONTENTS

1. INTRODUCTION

Icelandic freezing-trawlers have brought about increasing sales of whole-frozen redfish (*Sebastes marinus* and *Sebastes mentella*) to Japan, where quality demands are high. The most important quality factor for the retail value of whole-frozen redfish is the redness of the skin, as a pale colour of the skin indicates poor raw material quality or long storage. The bright red colour in *Sebastes* species is due to carotenoids pigments, primarily astaxanthin and tunaxanthin (Simpson, 1982). Profound studies on eighteen species of sea water red skinned fishes (Tsukunda, 1972) showed that carotenoids pigments in the fish skin are very sensitive to oxidation and easily break down during processing and storage. Tsukunda and co-workers found out that the stability of pigments differed with species and the red pigment astaxanthin was found to be less stable than yellow pigments. The discoloration took place rapidly in sunlight and was closely related to the intensity of irradiation of near-ultraviolet rays and to oxidative lipoxidase-like enzyme that exist in the skin tissue. The enzyme had an optimum pH from 6.8 to 7.0 and the optimum temperature was 20° to 25°C. Discolouring activity by the enzyme was inhibited with fat soluble antioxidants such as dibutyl hydroxytoluene (BHT) and butyl hydroxyanisol (BHA) but water soluble antioxidants such as ascorbic acids and its isomers were not effective. Copper salts on the other hand gave accelerating effect. The author (Tsukunda, 1972) concluded that in the skin tissues of red fishes occurs a kind of lipoxidase-like enzyme that participates in discoloration of carotenoid pigments together with physical and chemical discoloration.
All the same sodium erythrobate (*iso-ascorbate*) is used in the fish industry instead of the fat-soluble antioxidants for redfish dipping during processing to minimise discoloration of the skin. Maybe this is due to consumers opposition to synthetic antioxidants such as BHA and BHT and the fact that sodium erythrobate is a natural antioxidant. Sodium erythrobate is a reducing agent and has been shown to prevent colour loss of rockfish skin (*Sebastolobus alascanus*) (Wasson et al., 1991). Although sodium erytrobate has been used for redfish dipping for some time there seems to be many questions unanswered about the usage of this chemical. Is sodium erythrobate essential for preserving the skin colour, does it matter where in the processing line it is used, does time have any influence in that matter and does it have different effect on different redfish species? The purpose of this project was to study erythrobate, for befitting usage of this chemical during processing of whole frozen redfish, aiming to preserve as red a colour of the skin as possible.

2. MATERIALS AND METHODS

2.1. Fish sampling and handling

Redfish (*Sebastes mentella*) and orange redfish (*Sebastes marinus)* was caught by trawl on Reykjaneshryggur-fishing ground, southwest of Iceland in October 1996. The fish was immediately headed and gutted in machine on board a freezer trawler. Undamaged fish, without parasites were selected for the trials, weighing 300-500 g

and grading 3 in colour score by visual colour grading for redfish (Icelandic Seafood International Ltd.). The fish were divided and tagged individually into 8 lots of 48 fish each. The fish was measured for skin colour using a Minolta Chroma Meter in the L*a*b* measuring mode. Each lot was packed into four, wax coated cartons (7 kg). Twelve tagged fish were packed into each carton and filled up to seven kg with additional redfish. Plastic film (70 x 100 x 0.003 cm) was placed inside the carton to wrap around the fish-block for making a double plastic film layer at the top. The blocks were quick-frozen in a plate freezer to -23°C and then glazed after unwrapping the surface of the blocks and spaying it with water (1 l). The fish were rewrapped and the cartons turned upside down for the water to freeze on the top of the fish block. The cartons were finally packed three together in black plastic bags inside cardboard boxes for further frozen storage at -25°C.

2.2. Experimental setup

Conventional processing line for whole frozen redfish on board freezing trawler was as following:

Heading - Dipping in 1% erythrobate - Grading - Packaging - Freezing - Glazing.

Fish from each lot was treated with one of the following methods: (1) Control, conventional processing, fish dipped in 1% sodium erythrobate (Yama Products B.V., Netherlands) in seawater. (2) Delay before processing, fish kept for 2 hours at ambient temperature before processing. (3) Delay on ice before processing, fish kept for 2 hours on ice before processing. (4) No erythrobate dipping during processing. (5) Glazing, conventional processing and glazing with 1% sodium erythrobate. (6) Orange redfish-control, conventional process. (7) Orange redfish-glazing, conventional processing and glazing with 1% sodium erythrobate.

2.3. Colour measurements by Chroma meter

The skin colour of redfish was measured by a Minolta CR-300 Chroma meter (Minolta Camera Co., Ltd., Osaka, Japan) in the L*a*b* measuring mode (CIE 1976) with CIE Illuminant C. Equal distances in this system approximately equal perceived colour differences. L* is the lightness variable (L* = 100 is white and L* = 0 is black), a* and b* are the chromaticity coordinates, where +a* stands for red and -a* stands for green, whereas +b* stands for yellow and -b* stands for blue. For evaluation of change in colour by time, tagged fish were measured for L*a*b values before freezing and then again on sampling. Results are given as change in initial colour; ΔL^*, Δa^*, Δb^* and total colour difference, defined by:

$\Delta E^*_{ab} = \sqrt{((\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2)}$.

On sampling one carton from each treatment group was removed from the freezer, allowed to thaw in the closed carton for 21 h at 17 ± 1°C. At that time the fish were just thawed enough to enable skin colour measurements without difficulties. The colour was measured after 1, 3, 6 and 12 months frozen storage. The same fish was measured in three locations, giving the average colour value for head, middle and tail region of each fish. Each fish was measured on the left side, just below the lateral line and specific locations were, behind the pectoral fin, just above the vent and behind the

anal fin. Colour change during thawing was measured in the same way but allowing the fish block to thaw in closed cartons before measuring for up to 48 hours at 17 ± 1°C. Results are given as change in colour from 21 hours thawing time.

2.4. Sensory colour evaluation

The skin colour was evaluated on headed and gutted fish. Visual colour evaluation was based on a five-point scale for redfish (Icelandic Seafood International Ltd.) for 5 being the reddest.

2.5. Statistical analysis

Results shown are based on average calculations for each sample group. Tukey HSD multiple comparison method was used to find if significant difference ($p \leq 0.05$) was between averages of sample groups for each sampling.

3. RESULTS & DISCUSSION

3.1. Colour of redfish after treatment and frozen storage

The initial redfish skin colour values measured by L*a*b* scale that represented visual colour score 3 are shown in Table 1.

Table 1. Mean initial L*a*b* values for skin colour of redfish and orange redfish.

	L*	a*	b*
Redfish	59.0 ± 2.4^{a}	16.2 ± 2.4^{a}	15.9 ± 2.2^{a}
Orange redfish	58.2 ± 1.8^{b}	13.6 ± 2.7^{b}	20.8 ± 2.3^{b}

$^{a-b}$ Means within a column not sharing a common letter were significantly different ($p \leq 0.05$).
The mean consists of values from 96 fish from pre-frozen control and glazing groups, combining values from head, middle and tail locations of each fish.

Redfish and orange redfish differ in all measured L*a*b* values. Orange redfish is darker (L* = 0 is black and L* =100 is white), more yellow (b* = yellow) and less red (a* = red) than redfish. This is not surprising because the red colour of these species shows visual difference, as redfish appears to be more pink and orange redfish appears to be more orange in colour besides being darker.

Table 2. Mean L* values for skin colour of redfish and orange redfish with Sodium erythrobate treatment and frozen storage time.

Sodium erythrobate treatment	Storage time, months at -25°C[f]				
	0	1	3	6	12
Redfish:					
Control	59.7 ± 2.3[ac]	56.2 ± 2.1	56.4 ± 2.5	55.7 ± 2.2[a]	57.7 ± 2.2[a]
None	59.1 ± 2.2[ad]	57.6 ± 1.9	58.4 ± 1.6	58.0 ± 1.5[b]	57.9 ± 1.8[a]
After 2 h delay	61.0 ± 1.7[b]	57.3 ± 2.0	57.0 ± 2.2	57.1 ± 1.5[ab]	57.2 ± 1.8[ab]
After 2 h delay on ice	60.1 ± 2.1[ab]	56.7 ± 1.1	56.8 ± 2.2	56.9 ± 2.0[ab]	57.3 ± 1.7[a]
Control and in glazing	58.3 ± 2.4[d]	56.2 ± 1.8	57.2 ± 1.7	56.2 ± 1.7[ab]	55.1 ± 2.1[b]
Orange redfish:					
Control	58.0 ± 1.7[a]	54.8 ± 1.4[a]	55.6 ± 1.3[a]	55.8 ± 1.7[a]	54.4 ± 2.4[a]
Control and in glazing	58.4 ± 1.8[ab]	55.4 ± 1.8[ab]	54.7 ± 1.5[a]	54.5 ± 1.6[a]	54.8 ± 1.6[a]

[a-d] Means within each redfish column not sharing a common letter were significantly different ($p \leq 0.05$).
[e] At 0 month the mean consisted of pre-frozen values from 48 fish, whereas means for 1, 3 and 6 months were computed from 12 thawed fish, combining values from head, middle and tail locations of each fish in every case.

Table 3. Mean a* values for skin colour of redfish and orange redfish with Sodium erythrobate treatment and frozen storage time.

Sodium erythrobate treatment	Storage time, months at -25°C[e]				
	0	1	3	6	12
Redfish:					
Control	16.3 ± 2.3[a]	13.9 ± 1.9[a]	13.5 ± 1.5[a]	13.7 ± 1.5[a]	13.3 ± 1.4[a]
None	13.1 ± 3.1[d]	10.1 ± 2.4[b]	9.4 ± 2.0[b]	9.0 ± 2.0[b]	10.3 ± 2.3[c]
After 2 h delay	11.0 ± 2.5[bc]	9.5 ± 1.6[b]	9.8 ± 2.3[b]	11.1 ± 2.2[bc]	12.0 ± 2.5[ac]
After 2 h delay on ice	12.7 ± 3.0[d]	9.9 ± 2.3[b]	11.4 ± 2.1[ab]	10.3 ± 2.6[b]	12.2 ± 1.6[ac]
Control and in glazing	16.2 ± 2.4[a]	13.2 ± 1.7[a]	12.4 ± 1.3[a]	12.9 ± 1.8[ac]	15.6 ± 1.9[b]
Orange redfish:					
Control	13.6 ± 2.8[a]	11.2 ± 1.5	11.3 ± 1.7[ab]	11.3 ± 1.9[ab]	14.1 ± 2.1[a]
Control and in glazing	13.7 ± 2.6[a]	11.3 ± 2.1	12.9 ± 1.9[a]	12.0 ± 1.6[a]	13.2 ± 1.5[a]

[a-d] Means within each redfish column not sharing a common letter were significantly different ($p \leq 0.05$).
[e] At 0 month the mean consisted of pre-frozen values from 48 fish, whereas means for 1, 3 and 6 months were computed from 12 thawed fish, combining values from head, middle and tail locations of each fish in every case.

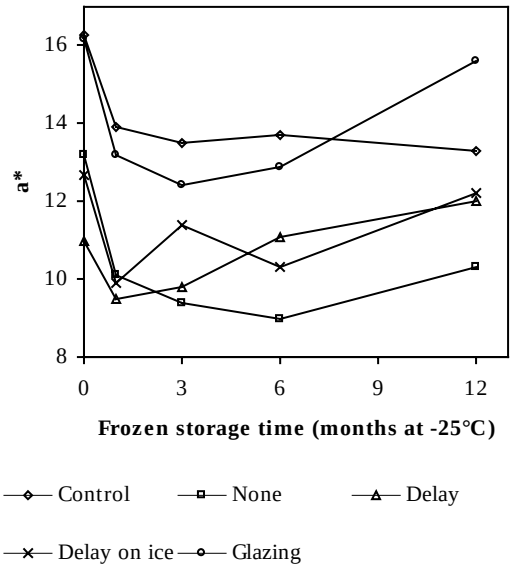
Table 4. Mean b* values for skin colour of redfish and orange redfish with Sodium erythrobate treatment and frozen storage time.

Sodium erythrobate treatment	Storage time, months at -25°C[e]				
	0	1	3	6	12
Redfish:					
Control	16.0 ± 2.0[ab]	13.0 ± 1.5[a]	12.6 ± 1.7	13.7 ± 2.3	13.2 ± 1.5[a]
None	16.2 ± 2.7[a]	11.1 ± 1.0[ab]	11.4 ± 1.8	11.5 ± 1.9	13.3 ± 2.1[a]
After 2 h delay	14.6 ± 2.2[b]	10.8 ± 2.2[b]	12.8 ± 1.8	12.7 ± 1.3	13.9 ± 2.2[ab]
After 2 h delay on ice	15.4 ± 2.4[ab]	11.7 ± 1.4[ab]	12.7 ± 1.8	12.2 ± 1.7	13.8 ± 1.6[ab]
Control and in glazing	15.8 ± 2.4[ab]	12.5 ± 1.4[ab]	12.0 ± 2.2	13.7 ± 2.4	15.9 ± 1.4[b]
Orange redfish:					
Control	21.0 ± 2.5[a]	15.7 ± 1.6	15.8 ± 1.5[a]	16.4 ± 1.7	19.1 ± 1.5[a]
Control and in glazing	20.6 ± 1.9[a]	15.8 ± 1.1	16.7 ± 1.2[a]	16.5 ± 1.4[a]	17.4 ± 1.3[b]

[a-c] Means within each redfish column not sharing a common letter were significantly different ($p \leq 0.05$).
[e] At 0 month the mean consisted of pre-frozen values from 48 fish, whereas means for 1, 3 and 6 months were computed from 12 thawed fish, combining values from head, middle and tail locations of each fish in every case.

Tables 2, 3 and 4 show the L*a*b* values for redfish skin colour with treatment before and during frozen storage. Delay before processing influenced the lightness (L*, Table 2) of the skin colour prior to freezing and resulted in higher L* values than other redfish groups. Icing during such delay (delay on ice-group) reduced the L* value. This indicates that immediate sodium erythrobate dipping during processing reduced the lightening of the skin. Freezing and frozen storage resulted in darkening of the skin of all treatment groups already after one month frozen storage. There was little significant difference in the lightness of the skin between treatment groups during frozen storage until after twelve months storage when the glazing group was considerably darker in colour than other redfish treatment groups. There was no significant difference in lightness of orange redfish with treatment during frozen storage.

Different treatment before freezing resulted in significantly redder (a*, Table 3) skin colour of the control group and the glazing group compared to other treatment groups. The delay group was on the other hand paler than all other treatment groups before freezing. In general freezing and frozen storage resulted in paler colour after one month in frozen storage but diminish of red colour did almost stop from that time. Most treatment groups showed some enhancement of red colour during the frozen storage period, especially the delay groups and the glazing group. The control and the glazing group were redder than other treatment groups during frozen storage until twelve months storage when the glazing group became significantly redder than the control group with almost as high red value as its pre-frozen value. There was no significant difference in redness between the orange redfish treatment groups during frozen storage.
Figures 1a and 1b show the red colour (a*) as the most representative of the evolution occurring in redfish skin pigment with treatment and time during frozen storage.



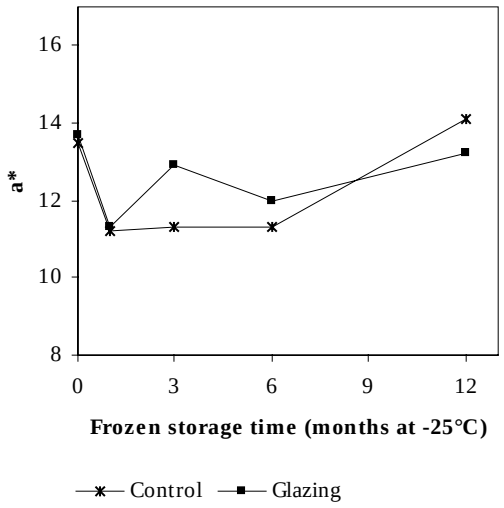


Figure 1a. Redfish *Figure 1b. Orange redfish*
Effect of sodium erythrobate treatment on red colour (a) of redfish skin during frozen storage.*

Delay before processing resulted in the lowest yellow colour (b*, Table 4) before freezing and also after one month frozen storage. No significant difference was observed between groups from one month till twelve months frozen storage when the glazing group showed the highest yellow score. Yellow colour faded in all groups after one month frozen storage, compared to their pre-frozen yellow scores, but increased again during further frozen storage. There was no significant difference in yellow colour between the orange redfish treatment groups until twelve months frozen storage, when the control croup was more yellow than the glazing group.

3.2. Colour change during frozen storage

Results of mean colour changes for the same lot of fish measured before freezing and again on sampling during frozen storage are compiled in Tables 5 to 8. Values for ΔL*, Δa* and Δb* indicate the change from the pre-frozen, initial colour. A value close to zero represents little or no change in colour. Figure 3 and 4 show the total change of colour as ΔE*. The smaller the value of ΔE* the closer the samples are to a perfect match to their initial colour.

The change in lightness (ΔL*) was negative or from higher values to lower L* values (see also Table 2). This indicates that the skin gets darker by time in frozen storage. Most of the darkening took place shortly after freezing, or within one month of frozen storage, except in the glazing group where darkening continued throughout the storage period. The darkening was smallest for the group where no sodium erythrobate was used and highest in the delay groups in the beginning of the storage period. On the other hand the delay groups were the only treatment groups that got whiter during frozen storage, but they were far from reaching their initial L* values. The ΔL* for the orange redfish groups was very similar to the redfish control and unaffected by treatment or storage time with almost no change in lightness from one month frozen storage. Darkening of the redfish skin after freezing is not in agreement with colour studies on rockfish (*Sebastolobus alascanus*) during frozen storage (Wasson et al., 1991). The rockfish skin lightened particularly in the beginning of the frozen storage. The explanation for this difference may be because the pigments in these related species are somewhat different and also their mechanisms of colour degradation.

Table 5. Mean ΔL* values for skin colour of redfish and orange redfish with Sodium erythrobate treatment and frozen storage time.

	Storage time, months at -25°C			
Sodium erythrobate treatment	1	3	6	12
Redfish:				
Control	-3.6 ± 1.4^{ad}	-2.9 ± 1.7^{abcd}	-3.0 ± 2.0^{ab}	-3.3 ± 1.7^{a}
None	-1.1 ± 2.0^{b}	-0.9 ± 1.8^{a}	-1.2 ± 1.9^{a}	-1.4 ± 1.2^{b}
After 2 h delay	-4.1 ± 2.2^{ac}	-4.4 ± 1.7^{bc}	-3.9 ± 1.5^{b}	-2.9 ± 1.7^{ab}
After 2 h delay on ice	-2.9 ± 1.3^{abcd}	-3.3 ± 1.7^{bd}	-4.2 ± 1.5^{b}	-2.3 ± 1.8^{ab}
Control and in glazing	-1.6 ± 2.4^{bd}	-1.9 ± 1.3^{ad}	-2.4 ± 1.6^{ab}	-2.8 ± 1.5^{ab}
Orange redfish:				
Control	-2.6 ± 1.7	-2.7 ± 1.8^{a}	-3.2 ± 1.9	-2.9 ± 1.0^{a}
Control and in glazing	-3.3 ± 1.8	-3.9 ± 1.4^{ab}	-3.2 ± 1.2	-3.6 ± 1.6^{a}

[a-d] Means within a column not sharing a common letter were significantly different ($p \leq 0.05$).
The mean consisted of value from 12 fish, combining values from head, middle and tail locations of each fish.

Table 6. Mean Δa* values for skin colour of redfish and orange redfish with Sodium erythrobate treatment and frozen storage time.

	Storage time, months at -25°C			
Sodium erythrobate treatment	1	3	6	12
Redfish:				
Control	-3.2 ± 1.1[ab]	-2.6 ± 1.5[a]	-3.2 ± 2.0[ac]	-1.7 ± 2.3
None	-4.1 ± 2.0[a]	-3.5 ± 1.7[a]	-3.3 ± 1.8[c]	-2.8 ± 2.5
After 2 h delay	-1.4 ± 1.8[b]	0.1 ± 1.6[b]	0.0 ± 1.2[b]	-0.5 ± 2.1
After 2 h delay on ice	-2.9 ± 1.6[ab]	-2.5 ± 2.1[a]	-1.0 ± 1.7[bd]	-0.7 ± 1.9
Control and in glazing	-3.2 ± 1.4[ab]	-3.4 ± 1.0[a]	-2.4 ± 1.8[cd]	-1.5 ± 1.7
Orange redfish:				
Control	-2.1 ± 1.7	-1.8 ± 1.8[ab]	-2.1 ± 1.8	-0.4 ± 1.8
Control and in glazing	-2.4 ± 1.9	-0.5 ± 1.4[a]	-2.2 ± 1.6	-0.2 ± 1.6

[a-d] Means within a column not sharing a common letter were significantly different ($p \leq 0.05$).
The mean consisted of value from 12 fish, combining values from head, middle and tail locations of each fish.

Table 7. Mean Δb* values for skin colour of redfish and orange redfish with Sodium erythrobate treatment and frozen storage time.

	Storage time, months at -25°C			
Sodium erythrobate treatment	1	3	6	12
Redfish:				
Control	-3.8 ± 1.5[ab]	-3.1 ± 1.4[ab]	-2.9 ± 2.5[ab]	-1.9 ± 2.2[ab]
None	-5.4 ± 2.0[a]	-4.5 ± 1.8[a]	-4.0 ± 2.5[a]	-3.5 ± 2.1[a]
After 2 h delay	-3.1 ± 1.7[b]	-1.6 ± 1.5[b]	-1.8 ± 1.5[ab]	-1.7 ± 2.1[ab]
After 2 h delay on ice	-3.2 ± 1.7[b]	-2.5 ± 1.6[ab]	-2.6 ± 1.6[ab]	-3.0 ± 1.5[ab]
Control and in glazing	-3.3 ± 1.5[ab]	-3.5 ± 1.4[ab]	-1.2 ± 1.8[b]	-0.8 ± 1.8[b]
Orange redfish:				
Control	-5.2 ± 1.4	-4.5 ± 1.7	-4.5 ± 2.4	-2.9 ± 1.9
Control and in glazing	-4.9 ± 1.9	-4.3 ± 1.1	-3.9 ± 2.1	-2.8 ± 1.3

[ab] Means within a column not sharing a common letter were significantly different ($p \leq 0.05$).
The mean consisted of value from 12 fish, combining values from head, middle and tail locations of each fish.

The explanation for this difference may be because the pigments in these related species are somewhat different and also their mechanisms of colour degradation.

The change in red scores (Δa*) were highest after one month frozen storage but turned lower with time for all redfish groups. This indicates that the fade of red colour is highest shortly after freezing but appears to improve with time in frozen storage. The change in the delay group was the smallest or around zero from three months frozen storage. The group that got no erythrobate dipping showed the highest change in a*, indicating highest fade of red colour, but as other redfish groups appears to improve with time in frozen storage. The Δa* for the orange redfish was rather constant from one to six months but improved after twelve months frozen storage. Improvement during prolonged frozen storage on red colour in fish has been reported in frozen storage studies on trout fillets (No and Storebakken, 1991). In this study on frozen storage stability of carotenoids and colour of trout fillets the authors speculate on a possible explanation for this higher intensity of red colour with frozen storage. Their idea is that it may be due to changes in light absorption and scattering caused by

freeze denaturation of proteins or the changes may have been caused by exposure of carotenoids to a more polar, water-rich environment causing a shift toward more red.

The change in yellow colour scores (Δb*) shows a similar pattern as the change in red scores. Processing without sodium erythrobate resulted in highest fade in yellow colour but the least discoloration was found in the glazing group and in the group that got delay before processing. The reason for so little fade in colour in the delay group during frozen storage may most possibly be due to the fact that the colour had already faded significantly during the delay before processing (see Table 2). All groups gained yellow colour from one months time, but the delay groups the least. The Δb* for the orange redfish was rather high after one month frozen storage but improved for both treatment groups from that time. Beneficial effect of prolonged frozen storage on yellow colour in fish has also been reported on frozen storage studies on trout fillets (No and Storebakken, 1991).

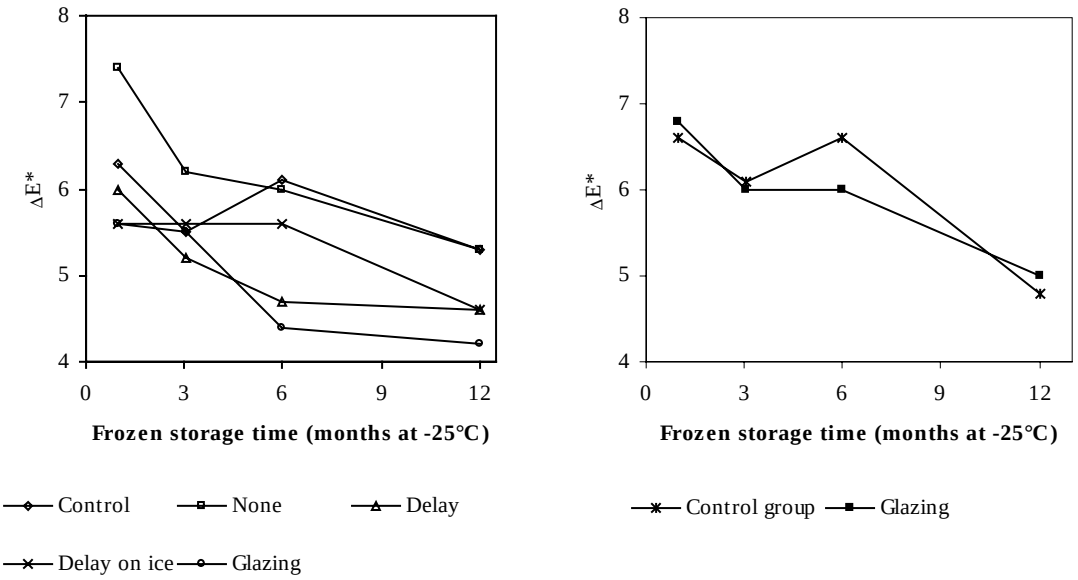


Figure 2a. Redfish *Figure 2b. Orange redfish*

Total colour change (ΔE) of redfish skin with sodium erythrobate treatment and storage time.*

The total colour change (ΔE*) tends to get lower during time in frozen storage in all treatment groups. The change was highest after one month frozen storage for most of the groups. Processing without sodium erythrobate resulted in highest total colour change throughout the storage period (7.1 ± 2.2 to 5.3 ± 2.4), but the glazing (5.5 ± 1.6 to 4.2 ± 1.1) and the delay groups showed the lowest changes. Still there was no significant difference between groups for the ΔE* values.

ΔE* is the total colour change and the smaller the value of ΔE* the closer the samples are to a perfect match to their initial, pre-frozen colour. When following the changes in colour of a product during processing and storage it can be taken for granted that the colour changes will be three-dimensional (Matthews, 1991). An ΔE* of less than 0.4 is below the threshold of human perception. First grade commercial matching tends to be up to ΔE* 0.9. Other less critical matching applications can have acceptable limits as high as ΔE* 4.0-5.0 (Parkers, 1994).

3.3. Colour change during thawing

For evaluation of prolonged thawing time on colour stability, the redfish skin colour was measured during thawing on twelve month frozen stored samples. The same fish was measured after 21, 26 and 48 hours and the colour compared with the first measurement. Results of the colour changes are compiled in Figures 3 to 6. Figures 3 to 5 show separate values for ΔL*, Δa* and Δb* scores. Figure 6 shows the total change of colour as ΔE* by time during thawing.

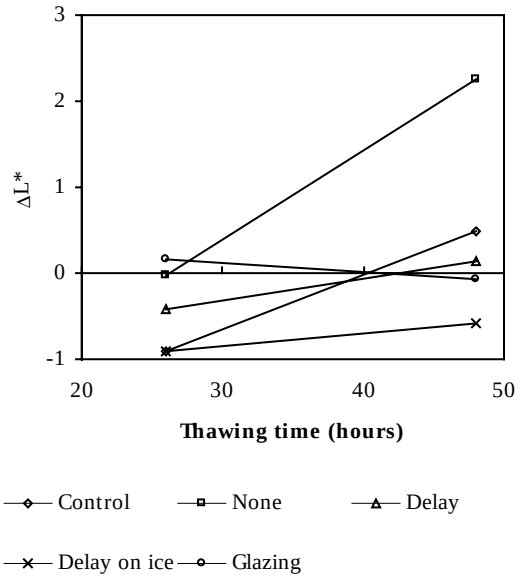


Figure 3a. Redfish

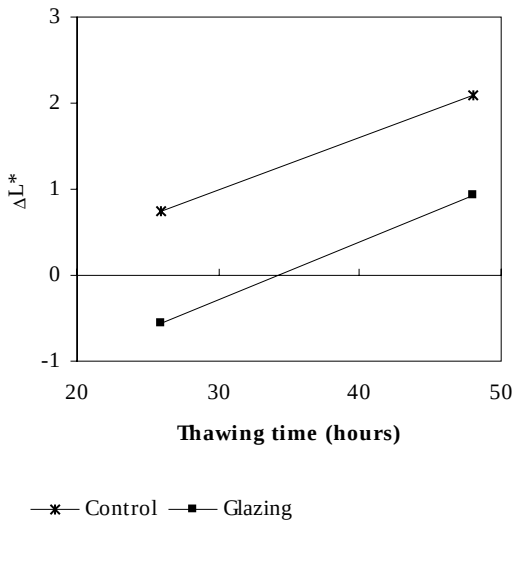
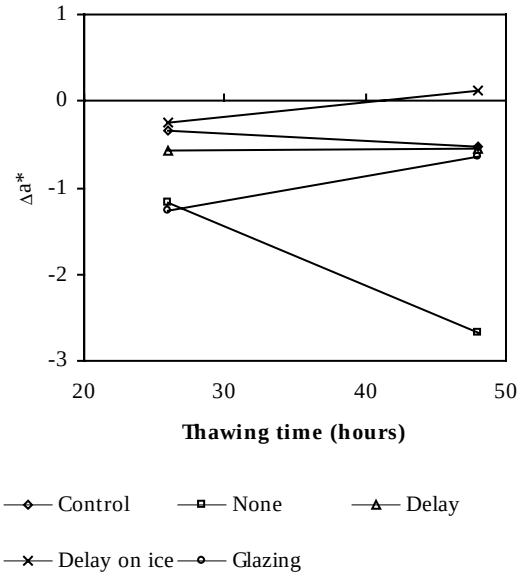


Figure 3b. Orange redfish

Changes in lightness (ΔL) of redfish skin with sodium erythrobate treatment during thawing.*

All redfish groups became lighter during thawing except the glazing group, which remained practically unchanged. The group that got no sodium erythrobate dipping showed the highest changes (ΔL* = 2.3) after 48 hours thawing time with a significantly ($p \leq 0.05$) more change than other treatment groups, except the control group ($p = 0.06$). The orange redfish control group showed almost as much change (ΔL* = 2.1) during thawing as the omission of sodium erythrobate redfish but the orange redfish glazing group showed much less change in lightness during thawing (ΔL* = 0.9), although there was not significant difference between these orange redfish groups ($p = 0.063$).

The change in red colour (Δa*) during thawing was rather small in all redfish treatment groups until after 48 hours thawing, when the group with omission of sodium erythrobate had changed significantly more towards fade of red colour than all other groups. The orange redfish control group showed significantly more changes in red colour compared to the orange redfish-glazing group after 48 hours thawing.



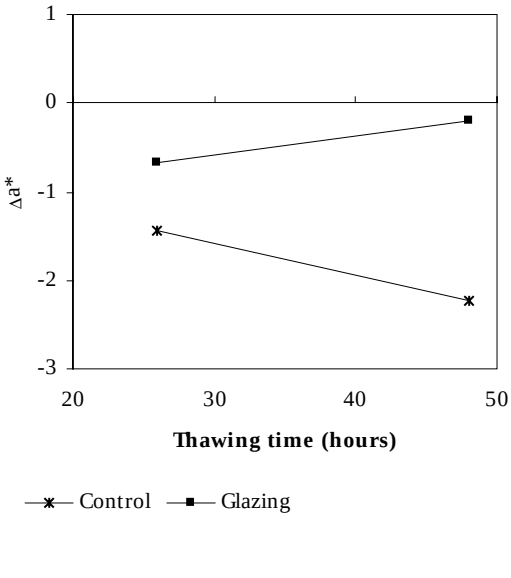
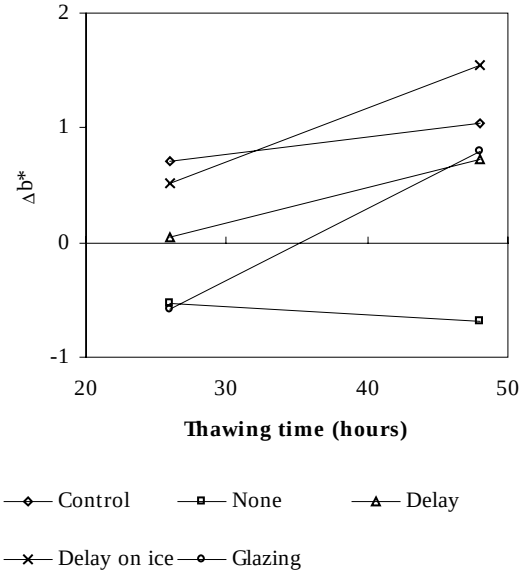


Figure 4a. Redfish *Figure 4b. Orange redfish*

Changes in red colour (Δa) of redfish skin with sodium erythrobate treatment during thawing.*

The yellow colour (Δb*) changed little in all groups in the beginning of thawing but seemed to improve during prolonged thawing time. This indicates that the yellow colour was more stable than the red colour. The group that got no erythrobate showed very little colour improvements and was significantly different from other treatment groups after 48 hours thawing time. The orange redfish control group showed highest changes at first, but improved during later thawing as well as the orange redfish-glazing group.



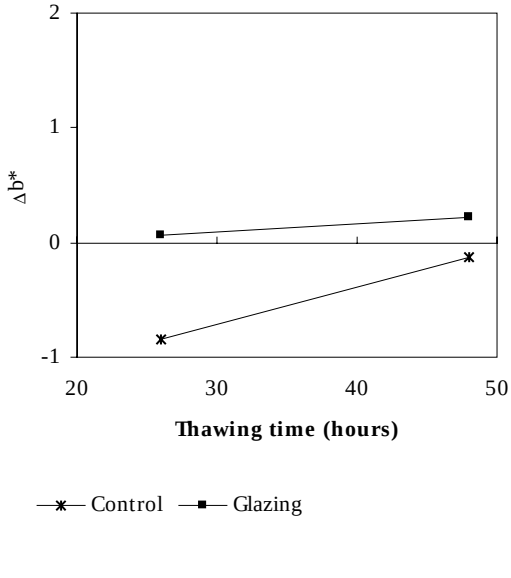


Figure 5a. Redfish *Figure 5b. Orange redfish*

Changes in yellow colour (Δb) of redfish skin with sodium erythrobate treatment during thawing.*

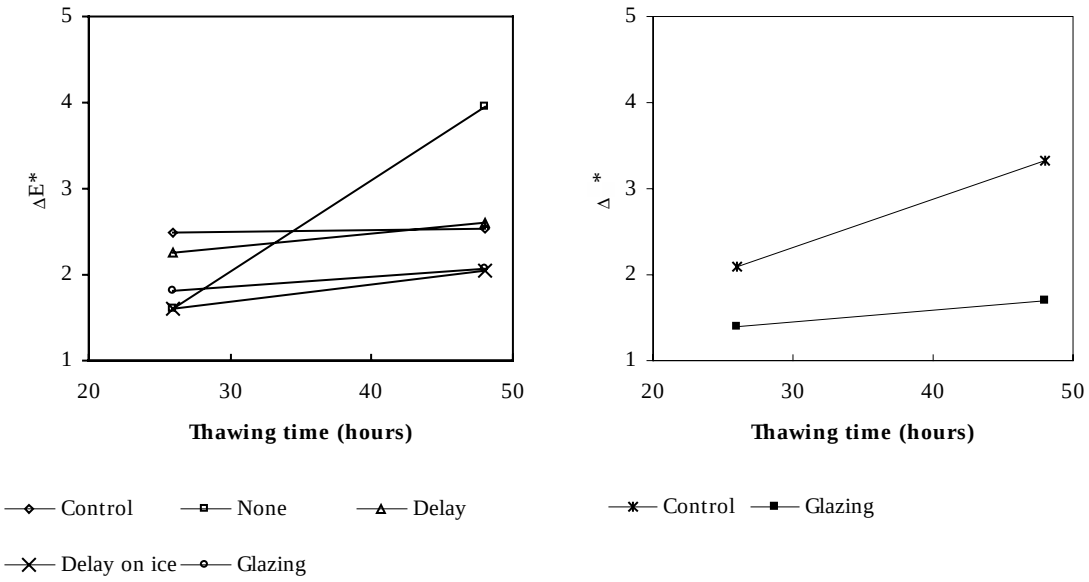


Figure 6a. Redfish *Figure 6b. Orange redfish*
Total colour change (ΔE) of redfish skin with sodium erythrobate treatment during thawing.*

The total colour change (ΔE*) increased in all groups during thawing. The highest change was found where no sodium erythrobate was used and this group was significantly different from both the glazing and delay on ice groups. The orange redfish control group showed significantly more total changes during thawing compared to the orange redfish-glazing group.

4. CONCLUSIONS

The highest fade of red skin colour of redfish occurred during processing or shortly after freezing. Sodium erythrobate treatment did not stop the discoloration of red colour, but slowed it considerably down both before and during frozen storage as well as during prolonged thawing. Glazing with sodium erythrobate seemed to hinder more colour change during thawing than sodium erythrobate dipping alone especially for the orange redfish.
These findings make it important to do more work on colour stability of whole frozen redfish. Most of the work in this project was aimed to track colour changes in redfish skin during frozen storage. As most fade of red colour occurred during processing and not during frozen storage it is of special concern to follow up the discoloration during the very first moments from catching. It is of great importance to the fishing industry to find out in what ways it is possible to alter processing for whole frozen redfish in order to preserve as red a colour as possible.

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