Food Control 95 (2019) 142–149

Contents lists available at ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Quality parameters of processed clusters of red king crab (*Paralithodes camtschaticus*) - Effects of live holding at 5 and 10 °C up to 92 days without feeding

Grete Lorentzen[a,*], Federico Lian[a,b], Sten Ivar Siikavuopio[a]

[a] Nofima AS, Norwegian Institute of Food, Fisheries and Aquaculture Research, Muninbakken 9-13, Breivika, P.O. Box 6122, NO-9291, Tromsø, Norway
[b] UCD Institute of Food and Health, University College Dublin, Belfield, Dublin 4, Ireland

ARTICLE INFO

Keywords:
Red king crab
Live holding time
Live holding temperature
Processing
Meat
Content
Yield

ABSTRACT

Red king crab (*Paralithodes camtschaticus*) has become a valuable resource in the Norwegian fishery. After landing, the crab is exported either as live or as processed into two cooked-frozen sections (i.e., clusters) to high-end market segments in Europe, Asia and in the USA. Live holding can be an alternative to processing right after landing, offering a new possibility to control the time before processing or live export. The live holding period can last, in absence of feeding, from some days up to as long as three months. The present study aimed to evaluate the effect of time and temperature on a series of quality parameters in red king crabs kept live without feeding at 5 and 10 °C up to 92 days. At day 0, 41, 62, and 92, the crabs were processed into cooked clusters followed by analyses. Meat content and cluster yield decreased significantly ($p < 0.05$) with live holding time and temperature as well as occurrence of moulting. Furthermore, the water content and pH of the cooked meat showed a significant increase as a function of live holding time, especially after 62 days of live holding at 10 °C. The live holding time and temperature have substantial negative effects on the product quality, likely related to the deterioration of muscle structure, that occur more markedly and earlier in the crabs kept at 10 °C (between 41 and 62 days) compared to their counterparts at 5 °C (between 62 and 92 days). The effects of live holding conditions appear more evident once the clusters are cooked compared to their raw counterparts. The results show that live holding time and temperature highly influence the quality of both live crabs and processed clusters. Thereby, a detailed knowledge and high control of live holding conditions are required to obtain an optimum quality of red king crabs.

1. Introduction

Red king crab (*Paralithodes camtschaticus*) have become important for the fish industries located in the northern parts of Norway (Lorentzen et al., 2018). In 2017, a total of 2131 metric tons of red king crab, live and processed, was exported from Norway amounting to NOK 509 million (Norwegian Seafood Council, 2018). Due to the appealing sensory properties of the meat, the product has attracted increasing interest among consumers, especially in high-end market segments in Europe, Asia and in the USA (Voldnes, 2017).

Nowadays, fishing of red king crab is a year-round activity in Norway, enabling the industry to be supplied with crabs irrespective of seasons (Lorentzen et al., 2018). After harvesting and landing, the red king crab is either kept live or processed into clusters. A cluster includes three walking legs and a claw assembled in a shoulder joint. The live holding of red king crab occurs either in containers on shore or in net pens close to the processing facilities and thus, enabling a flexible management of this resource. Also, live holding enables delivery to markets that require stability in terms of volume and quality. The duration of the live holding period depends on the welfare status of the crab, the market requirements to minimum meat content, and of course the fluctuations in the market price (Norwegian Seafood Council, 2018). Live holding after catch improves the welfare of the animal, and this is beneficial, especially in the case of long-distance transport (Siikavuopio & James, 2015). In fact, live holding may actually be required to facilitate recovery after a rough handling related to harvest and transport. This is particularly important for the crabs harvested from May. This will be after the moulting period that typically starts in March and ends in April. Recently-moulted crabs have a low meat content and are more fragile and vulnerable due to a thin and a soft shell (James et al., 2013).

The red king crab is a cold water adapted species normally found

* Corresponding author.
E-mail address: grete.lorentzen@nofima.no (G. Lorentzen).

https://doi.org/10.1016/j.foodcont.2018.07.041
Received 20 April 2018; Received in revised form 20 June 2018; Accepted 26 July 2018
Available online 27 July 2018
0956-7135/

between 1 and 10 °C (Christiansen, Sparboe, Saether, & Siikavuopio, 2015). Due to elevated seawater temperatures in the summertime, a higher mortality rate typically occurs during live holding and export (Siikavuopio, James, Olsen, Evensen, & Mortensen, 2016). Consequently, processing to clusters is preferred at this time of the year.

Processing starts with the slaughtering, i.e., splitting the crab into two clusters and removal of the carapace, stomach, and hepatopancreas. Afterwards, the clusters are drained, cleaned, and cooked. Methods for heat treatment of the clusters include boiling or steaming (Flick, Granata, & Marsh, 2009; Manuel, 2017; Siikavuopio et al., 2011). After the heat treatment and subsequent cooling, the clusters are subjected to freezing, either in a tunnel freezer or in a brine saturated with NaCl and tempered to −18 °C (Lorentzen et al., 2018). Nowadays, the majority of the red king crab clusters processed in Norway are exported as frozen (Norwegian Seafood Council, 2018). However, the clusters can alternatively be exported as fresh, preferably to markets close to Norway. In both fresh and frozen clusters, besides the sensory properties (e.g., odour, taste, texture and juiciness), the absence of double shell and the presence of a high meat content are also very important for the consumer.

The double shell refers to the extra inner membrane between the muscle and the exoskeleton that the crabs tend to develop about 1–2 months before the moulting. The presence of double shell is associated with a firm and tough texture of the meat (Stevens, 2014) which is considered as unacceptable by the consumer (Lorentzen, Skuland, Sone, Johansen, & Rotabakk, 2014).

The meat content refers to the spatial portion occupied by muscle in the cluster claw and legs. Factors influencing the meat content include season and location of harvest and also the physiological condition of the crab (e.g., the moulting stage) (Hjelset & Sundet, 2004; James et al., 2013; Siikavuopio & James, 2015; Siikavuopio et al., 2011, 2016; Stevens, 2014). Moreover, a lower meat content has often been observed in the clusters obtained from crabs with missing legs (S. I. Siikavuopio, personal communication). The meat content can be improved by feeding the crabs during the live holding period (James et al., 2013). Notably, the meat content is related to the yield, which can be defined as the final weight of the raw or cooked clusters relative to the weight of the whole raw crab. For this reason, a low meat content of both live crabs and processed clusters is considered unacceptable in many markets, and it could, therefore, lead to loss of market shares.

To our knowledge, the relationship between live holding conditions of adult male red king crab and the quality of processed clusters has not been published. Previously, it has been shown that live holding conditions of cod affect the final product quality (Akse & Midling, 1997). Thus, the aim of this study was to evaluate the quality of processed clusters of red king crab as a function of the live holding conditions. In detail, the crabs were kept live at 5 and 10 °C for up to 92 days without feeding. Sampling was performed at day 0, 41, 62, and 92, and the crabs were processed into cooked clusters the following day. The quality parameters studied included the meat content, yield, water content, pH and water holding capacity (WHC) of the product.

2. Material and methods

2.1. Harvest and live holding

In December 2016, adult male red king crabs were harvested by local fishermen in the North Cape area in the Barents Sea using square shaped commercial king crab pots. This specific period of the year was chosen as the meat content of the red king crab is high with a low between-exemplars variation. The crabs (N = 78) were transported live in a dry state covered with gel ice (Cold Ice, Inc., Oakland, CA, USA) in polystyrene boxes by air freight in approximately 3 h to the Aquaculture Research Station in Tromsø, Norway (~70°N). Upon arrival, the crabs were immediately placed in 6 m^3 tanks supplied with natural seawater (4 °C, 34‰ salinity) which was continuously UV-treated, filtered through a 150 µm sand filter and circulating at a flowing rate of 4 L min^{-1} (kg crab)$^{-1}$.

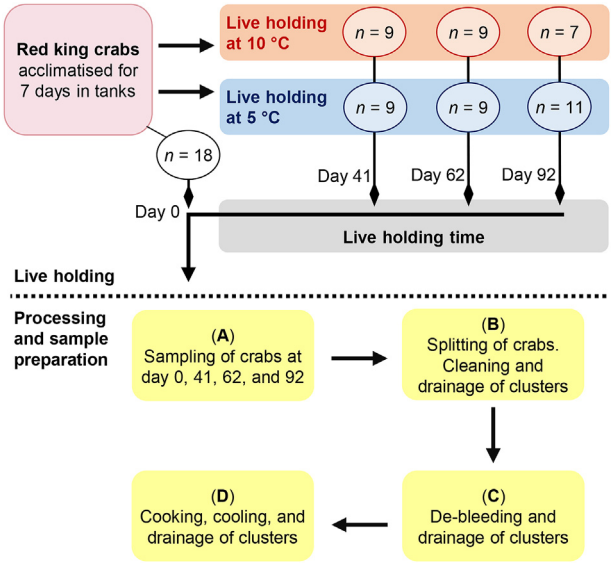

Fig. 1. Flowchart illustrating the experimental set-up for the live holding and the sequence of activities for crab processing and sample preparation. Processing steps are indicated in brackets with capital letters corresponding to steps of weight registration.

After an observation and acclimatization period of seven days, the first sampling was performed (n = 18, live holding time day 0) (Fig. 1). At the same time, the remaining crabs (n = 60) were equally distributed into six circular tanks (volume 700 L) supplied with continuously UV-treated, filtered, and circulating seawater as previously described. The water temperature was set at 5 °C (± 0.2) in three tanks whereas in the other three tanks the temperature was set at 10 °C (± 0.2). A temperature of 5 °C represents the recommended temperature for the animal, while 10 °C represents the maximum proposed temperature that the crab can be exposed to (Christiansen et al., 2015; Siikavuopio & James, 2015). During the experiment, no cannibalism was observed, and the crabs did not have mutilated or missing legs. Crabs from both temperature groups were sampled at day 41, 62, and 92 during the live holding period.

On each sampling day, 18 crabs were sampled from the tanks, transferred into polystyrene boxes and then covered with gel ice. The boxes were transported in 1 h from the Aquaculture Research Station to Nofima in Tromsø. The crabs were kept in the boxes in a dry state and processed the following day, within 15 h of their arrival. No mortality was observed upon arrival.

In total, 18 crabs (processed into 36 clusters) were sampled at day 0, while nine crabs (i.e., 18 clusters) from each live holding temperature were sampled after 41 and 62 days of live holding (Fig. 1). At day 92, 11 (i.e., 22 clusters) crabs held at 5 °C and seven crabs (i.e., 14 clusters) held at 10 °C were sampled. In each sampling, a balanced number of crabs was collected from each tank across the live holding temperature groups. By this, moulted exemplars were given priority, if present. In this way, it was possible to evaluate the influence of the live holding conditions to the moulting.

The weight of the total number of crabs eventually sampled and processed in this study (N = 72) ranged between 2158 and 2790 g, with an average weight (± standard deviation) equal to 2379 g (± 273).

2.2. Processing and sample preparation

The procedure for processing the red king crabs into clusters reflected the industrial processing and was maintained consistent throughout the entire experiment (Fig. 1). The processing started with