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# Liquid Holding Capacity and Liquid Leakage of Raw Salmon and Trout Fillets

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## Abstract

Liquid loss (i.e. loss of water and liquid fat) is an important property for salmonids when evaluating fish quality in production and as final product. It can be measured by several means, for example by liquid leakage or by liquid holding capacity. The present study examines how liquid leakage and liquid holding capacity of salmon and trout are influenced by fat content. Liquid leakage did not depend on fat content whereas the liquid holding capacity was lower for fish with high fat content. Thus the methods provide supplementary rather than equal information. Furthermore the water loss part was linear depending on liquid loss. The results indicate that fat is more loosely bound in trout than in salmon. These findings may be of immediate relevance to quality control of high-value fat fish products, to assessment of raw material properties, to an efficient treatment in the production and to process control.

**Keywords:** liquid loss, salmon, trout, fat content

## 1. Introduction

The ability to retain liquid, i.e. water and non-solid fat if present, in the structure during processing and storage is a very important feature for many muscle-based food as it may affect the safety, the quality and the price of the product. The term liquid holding capacity refers to the ability to prevent both water and lipid from being released from the structure (Hermansson, 1986). The ability of fish muscle to retain its own liquid has traditionally been described by the term water holding capacity (WHC) as most research has been conducted on lean fish species (Eide et al., 1982), where liquid mainly is water. However, given the increasing production of farmed salmon and trout products with higher lipid content, more focus has been directed to define liquid loss as loss of both water and lipid. Recently, it has been shown that part of the lipid will stay in a liquid state at temperatures far below traditional storing temperatures for frozen fish (Tolstorebrov et al., 2014) and thus fatty fish may lose both water and lipid during processing. Therefore, the term 'liquid holding capacity' has been introduced.

Lipid and water together constitute about 80% of the fish muscle. Depending on the properties of the flesh and the way it is treated, liquid with various amounts of water and lipid may be lost during processing. The ability of the muscle to hold liquid is important to the consumer because it influences the texture such as juiciness and thereby contributes to the overall product quality (Olsson et al., 2003).

Two main approaches have been reported to determine liquid loss on intact or minced fish muscle - either as liquid leakage or as liquid holding capacity. Liquid leakage is liquid absorbed by a filter paper when leaking from intact muscle without applying a compressive force (Mørkøre et al., 2002; Rørå et al., 2003; Mørkøre et al., 2007). Liquid holding capacity is the ability to withhold liquid in minced or chopped muscle during a centrifugation (Jauregui et al., 1981; Eide et al., 1982; Hermansson, 1986; Gómez-Guillén et al., 2000).

Common for the properties is that they are highly dependent on experimental conditions. The values are among other factors dependent on standardised sample preparation when using pieces of whole muscle or coarse- or fine-minced muscle. And sampling is of outmost importance: biological factors like chemical composition, biological state and post-mortem processes influence the fish flesh quality and liquid holding capacity (Ofstad, 1995) and these factors vary from individual to individual (Mørkøre et al., 2002). However, there is still limited knowledge on how liquid leakage and liquid holding capacity are influenced by fat content, species and processing.

The present paper discusses how liquid loss in two species of salmonides is influenced by the fat content using the centrifugation method and the liquid leakage method, and how liquid leakage is composed. Also, similarities and dissimilarities between information obtained by the two methods is explored.

## 2. Materials and Methods

Farmed salmon (11-20% fat) and farmed rainbow trout (4-11% fat) were used in order to cover a broad interval of fat content (Table 1). In total, 18 Atlantic salmon (*Salmo salar*) farmed in Norway, and 40 rainbow trout (*Oncorhynchus mykiss*) farmed in Denmark, were analysed.

### 2.1 Preparation of samples

The fish were filleted by hand, trimmed and analysed one day after filleting.

The sampling scheme was similar to that described in Løje et al. (2007). Three pieces were cut from the

fillet: piece one was in front of the dorsal fin and above the lateral line, piece two was under the dorsal fin and above the lateral line, and piece three was behind the dorsal fin. Piece one and three were minced for 2 x 5 s at 5 °C in a Knifetec, 1095 Sample Mill (Foss Tecator, Sweden). The mince from piece one was used for determination of water content and of liquid holding capacity. Piece two was used for determination of liquid leakage, and the mince from piece three was used for determination of fat and salt content.

## 2.2 Methods

### 2.2.1 Liquid leakage method (LL-method)

The method by Mørkøre et al. (2002) was used with some modification to determine the liquid leakage: A slice of untrimmed fish muscle (about 15 g) was placed on a weighed pad (7.5 x 12.5 cm) from Cryovac Lit Loc 800, wrapped in aluminium foil and kept at room temperature (22 to 24°C) for 20 h. A piece of nylon cloth was placed between the muscle and the pad to minimise the effect of capillary forces and the muscle from sticking to the pad. After removal of the muscle piece, the pad was weighed again, dried at 105 °C for 60 min in order to evaporate all the water and weighed for the third time. In the experiment with trout, the procedure was slightly modified due to the smaller fish size: the sample was reduced to about 10 g, a Whatman filter paper GF/A 125 mm was used instead of a Cryovac pad, and the sample was put in a closed Petri dish instead of wrapped in aluminium foil. The liquid leakage relative to the sample wet weight was calculated from the difference between the second and the first weighing, and the water part of the leaked liquid was calculated from the difference between the third and the second weighing. Four determinations were made for each sample.

### 2.2.2 Centrifugation method (LHC-method)

The liquid holding capacity was determined on 2 g mince using a modification of the centrifugation method by Eide et al. (1982). The sample was weighed, placed in plastic tubes with a special filter bottom (pore size 0.1 mm), centrifuged (1500 g, 10 °C, 5 min) and weighed again. The liquid loss by centrifugation was calculated as this weight difference in per cent of the initial weight of water and fat in the sample, and the liquid retained as 100 minus the liquid loss.

### 2.2.3 Salt content

The salt content was determined electrochemically by titration with AgNO<sub>3</sub> according to AOAC methods.

### 2.2.4 Water and dry matter content

The water content was calculated as the change in sample weight when 2 g mince was dried overnight at 105°C relative to the initial sample wet weight.

### 2.2.5 Fat content

The fat content was determined by a modified version of the Bligh & Dyer extraction method (Bligh and Dyer, 1959) using 10 g of mince and reduced volume of organic solvents.

## 2.3 Data analysis

The total liquid leakage (LL-value) and the water contribution (WL-value) to the leakage were calculated as described in the LL-methods section above. The fat contribution (FL-value) to the liquid leakage was calculated as:

$$FL = LL - WL[1 + \text{salt concentration (w/w)}]$$

with salt concentration being equal to salt content divided by water content of the samples, assuming that the salt was uniformly diluted in the water phase.

The liquid holding capacity, LHC was defined as the retained liquid during centrifugation determined as described above.

Statistical comparisons between LL and LHC were done by paired t-tests and comparisons between salmon and trout properties by unpaired t-tests. As multiple comparisons were made, the significance level for each single comparison was 0.5%, corresponding to an overall significance level of approx. 5%.

## 3. Results and discussion

The liquid leakage for fish varied between 1.5 and 4.5 % for all samples. The correlation between liquid leakage from the samples and their fat content was not high ( $r=0.57$ ) in the full data set (Figure 1a). However, the liquid leakage from farmed salmon representing high fat content was significantly higher compared with farmed trout representing low fat content ( $p < 10^{-5}$ ).

Figure 2 illustrates the part of the liquid leakage that was due to water leakage and fat leakage, resp. In general, most of the LL-value consisted of the WL-value, and more pronounced for salmon than for trout. In contrast, trout had a significantly higher FL-value than salmon ( $p=0.0013$ ).

Results from determination of the liquid holding capacity for the samples in relation to fat content are shown in Figure 1b. In general, the liquid holding capacity was over 90 % for both trout and salmon. Other studies have found similar high liquid holding capacities for salmon samples with fat content from 10.2 to 20.7 % (Rørå et al. 2003; Birkeland et al., 2004).

Liquid holding capacity showed a different relation to fat content than did liquid leakage: for both species, the fish with highest fat content showed more difficulty in holding the liquid determined as LHC (Figure 1). The LL-method gives a measure of the ability of the material to withhold water and lipid without severely changing the microstructure of the sample. In contrast the microstructure is markedly affected by mincing used in connection with the LHC-method. Even at 10 °C (the operating temperature of the LHC-method) some deposit fat in the fish muscle is in the liquid state, and destruction of cell structures enables fat in the fish with high fat content being more easily squeezed out from the cells during centrifugation. This indicates that fat is more loosely bound in trout than in salmon. Accordingly, the LL-value and the LHC-value were poorly correlated ( $r=-0.35$ ) which also agrees with the difference in patterns seen for LL- and LHC-values in relation to fat content. Salmon had a higher fat content and thus a lower water content.

### 3.1 Applicability of LHC- and LL-methods for quality assessment

The present paper demonstrates that two common approaches, measuring the liquid holding capacity and the liquid leakage by the liquid leakage method, provide supplementary rather than equal information. Furthermore, liquid leakage was not influenced by the fat content, whereas liquid holding capacity was lower for fish with high fat content. Thus, it is recommended to use both types of methods where applicable, in order to get as detailed picture as possible of this important quality parameter.

It was easy to divide the liquid leakage into the contributions from water and lipid leakage. A similar separation between water and fat holding capacity was also attempted in the present study but with limited success. However, collecting such data will provide a better understanding of the mechanisms of retaining liquid in the muscle food and thereby add to the knowledge needed for an optimal processing and storage and an efficient production control.

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Table 1: Information about the raw material.

	No. of fish	Size kg	Lipid content (%)	
			min	max
Salmon	5	6-7	14	20
Salmon	13	3-4	11	15
Rainbow trout	32	2-3	4	11

Figure 1. Dependence of (a) liquid leakage (LL) and (b) liquid holding capacity (LHC) on fat content. Symbols used: ●, data from salmon; ○, data from trout.

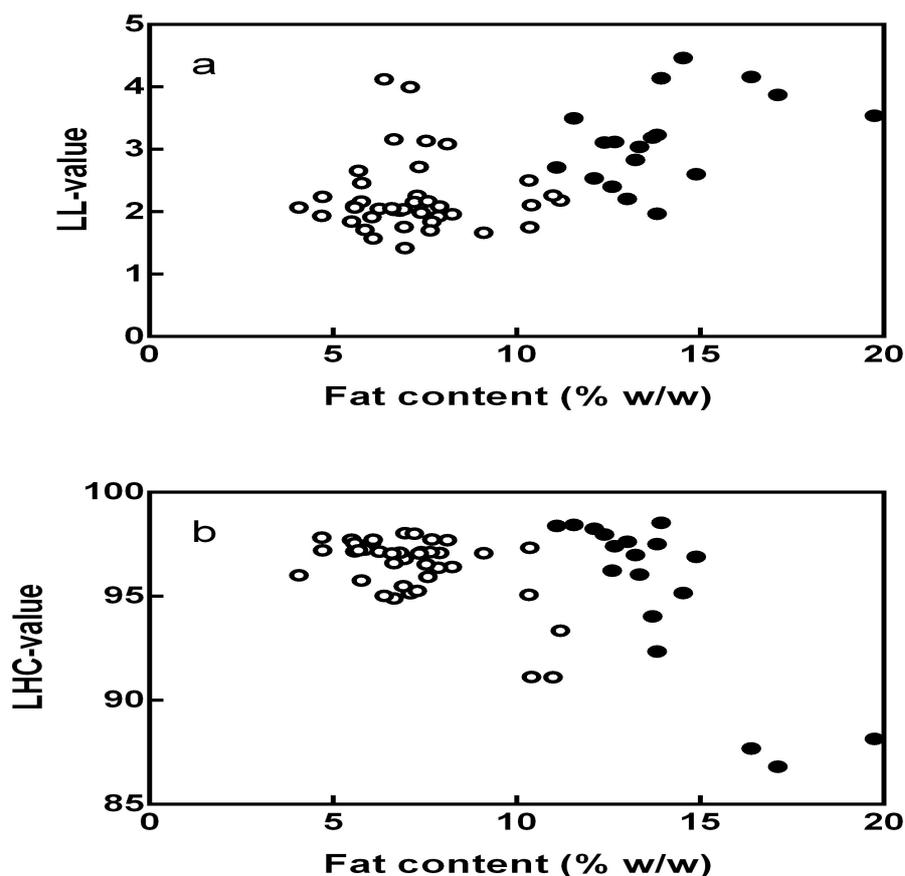


Figure 2. Composition of liquid leakage (LL).  
Panel a: Part of the LL-value coming from water leakage (WL). Panel b: Part of the LL-value coming from fat leakage (FL). Symbols used: ●, data from salmon; ○, data from trout.

