

RESEARCH NOTE

Physico-chemical and functional properties of roe from autumn spawning herring (*Clupea harengus harengus* L.)

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Various functional properties (viscosity, pH, emulsifying capacity, and emulsion stability) of roe from autumn spawning herring (*Clupea harengus harengus* L.) were evaluated in relation to their stage of maturity (three stages of maturity). Analysis of variance indicated that maturity stage did not significantly affect ($P > 0.05$) the various functional properties examined.

Keywords: roe, eggs, herring, maturity, functional properties.

INTRODUCTION

Fisheries and the fish industry represent a large part of the economic activities in the province of Quebec, Canada. Aside from entire fish, fish fillets and fish slices, fish roe represents a substantial volume of marketable products. During the reproduction period, roe can make up to 20% of the fish weight (McGurk *et al.*, 1980).

Although the market for fish roe products is year-round, the supply of roe is restricted by its seasonality. The latter is especially true in the province of Quebec where herring, lumpfish, and, to a lesser extent, cod and capelan roe are harvested. In the case of herring roe, the harvest is done in spring and in early fall, based on the two reproductive seasons. Presently, with the classification used in the industry, a large amount of roe is rejected on the basis of its appearance. Roe is removed at maturity, i.e. before spawning, and clas-

sified according to such criteria as intactness of the roe and a blood-free appearance. These criteria are important since roe is almost exclusively intended for the production of *kazunoko*, a product made from whole roe in brine, and exported for the Japanese market. In addition, *tarama*, which is a mayonnaise-like product, is manufactured from fish eggs. The successful production of *tarama* is dependent on the physical and functional properties of the utilized eggs (Stadelman & Cotteril, 1977).

Many parameters such as the type of species, the condition index of the fish, i.e. the ratio of the total weight to the cube of the length, and the state of maturity influence the composition of fish roe (Shatunovskiy, 1970; Vuorela *et al.*, 1979; McGurk *et al.*, 1980; Kaitaranta & Ackman, 1981; Tocher & Sargent, 1984; Henderson & Altamar, 1989). Depending on the stage of maturity, varying amounts of protein, lipoprotein, and some lipid components such as lecithin and other phospholipids are present (Stadelman & Cotteril, 1977; Vuorela *et al.*, 1979). In herring roe, the protein content increases with maturity until spawning, whereas the lipid content does not vary significantly (Vuorela *et al.*, 1979).

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The improvement and diversification of roe-based products are possible with a better knowledge of their physical and functional properties. Therefore, the purpose of this study is to evaluate specific properties, i.e. pH, viscosity, emulsifying capacity, and emulsion stability, of autumn-harvested herring roe at different stages of maturity.

MATERIALS AND METHODS

Sample preparation

Ninety samples of roe from autumn spawning herring (*Clupea harengus harengus* L.) were removed at the Société des pêches de Newport plant, Province of Quebec, the same day the herring were caught (near Chandler, Quebec). The gonads (the sex glands containing the roe) of the majority of the herring were at the spawning stage, stage V according to a classification scheme used in fish biology (Landry & McQuinn, 1988). Some female specimens had already started spawning (stage VI) (Holliday, 1960). The gonads were grouped into three categories which we arbitrarily named stages 1, 2 and 3, and which corresponds to the classification scheme used in commercial plants. This classification refers to intactness and blood-free appearance of the roe: stage 1 was attributed to yellow-colored gonads, free of blood, intact and firm. Stage 2 was given to gonads yellow to orange, slightly veined with blood vessels and still firm. Stage 3 corresponded to gonads that had started to empty themselves, and are reddish and limp. This latter type of gonad is rejected by the industry.

The roes were packed individually in sterile plastic bags, and kept on ice during transportation. Freezing at -30°C in a walk-in freezer was done 10 h after the extraction of the first gonads.

Determination of gonado-somatic index

The gonado-somatic index (GSI) was calculated for each of the 90 fishes by the percentage of the gonad weight over the total weight of the fish (McGurk *et al.*, 1980). The GSI provides a simple index of the relative size of the gonads.

Determination of salt-soluble proteins

The content of salt-soluble proteins was used as an index of protein stability during frozen storage

(Synch *et al.*, 1990). About 1 g of egg was used for the extraction, according to the method of Dyer *et al.* (1950), at the 3rd and 13th week of frozen storage. Protein content was determined using the Comassie Blue dye-binding assay (Bio-Rad Laboratories, 1992).

Measurement of viscosity and pH

Samples were analyzed after pooling them (three roes of the same stage were combined to make one sample), in order to obtain a volume large enough to measure the viscosity. After 10 weeks of frozen storage, samples were thawed at 4°C for 12 h. Each pooled sample was homogenized for 90 s with a small food processor (Black and Decker, Handy Chopper, Brockville, ON). The pH was measured immediately on the homogenate (temperature $\sim 10^{\circ}\text{C}$) and the homogenate was cooled to $5\text{--}6^{\circ}\text{C}$. Viscosity was measured with a Brookfield viscometer; model RVF (D. W. Brookfield Ltd, Cooksville, ON, Canada), spindles 2–4.

Emulsifying capacity

Twenty grams of eggs were placed in the small food processor, and, while running, soya oil was added slowly, until a mayonnaise-like emulsion resembling whipped butter was obtained. The addition of oil was continued until there was a visible break in the emulsion, i.e. the 'collapsing of the emulsion' was observed, at which time the amount of oil added was recorded. Emulsion capacity was expressed as ml of oil per g of eggs.

Emulsion stability

Emulsion stability was measured in duplicate by centrifugation of 50 ml of the emulsion previously obtained at $12000 \times g$ for 20 min, using an IEC (International centrifuge, model H-T (International Equipment Co., Needham, MA, USA). Stability was determined by measuring the volume of stable emulsion remaining over the total volume.

Statistical analysis

All statistical analyses were performed with SPSS (1983). A completely randomized design with 10 observations per stage of maturity was used. One-way analysis of variance (ANOVA model 1) was conducted on each of the five variables (GSI, pH, viscosity, emulsifying capacity, emulsion stability)

as a function of maturity. Pearson's correlation coefficients were also calculated for each combination of variables.

RESULTS AND DISCUSSION

The mean gonado-somatic index (GSI) indicated that roe from gonads at stages 2 and 3 represent advanced states of spawning (Table 1). The GSI of stage 1 (gonads yellow and firm) was slightly lower than previously reported (McGurk *et al.*, 1980), i.e. 16.6 in the present study compared to 18 reported by McGurk *et al.* This could mean that stage 1 includes mature gonads (stage V of Landry & McQuinn, 1988) and gonads partially spent (beginning of stage VI) or that there was simply a genetic variation in fish stock.

The pH of herring eggs for all maturity stages was approximately 5.7 (Table 1). Stodolnik (1990) obtained slightly higher pH values with Baltic herring eggs refrigerated at 2°C, i.e. pH 6.45 after 2 days and 6.1 after 9 days of refrigeration. Cheftel *et al.* (1985) reported that pH values of proteins in solution decrease during frozen storage, and that this decrease lowers the net charge of proteins and makes them more hydrophobic. The pH reflects the ionization stage of the molecules, and for proteins, phospholipids and the similar molecules, this ionization directly affects their viscosity and their capacity to emulsify lipids (Carpenter & Saffle, 1965).

Viscosity is a property that depends on several factors, including moisture level (73–77% for our samples, data not shown) and lipid content, but also on the type of proteins. This latter factor is often evaluated indirectly by protein solubility and can be significantly affected by frozen storage (Synch *et al.*, 1990). In the present study, the content of salt-soluble proteins was measured on two occasions, i.e. after 25 and 90 days, where the contents were $6.1 \pm 1.2\%$ and $7.4 \pm 2.0\%$, respectively. The fact that the content of salt-soluble proteins did

not decrease would imply that no adverse effects occurred after 10 weeks of storage at -30°C . Jimenez-Colmenero & Borderias (1983) reported a decrease of 30% in salt-soluble protein content between 0 and 30 days of frozen storage at -20°C , in samples of minced poutassou (*Micromesistius poutassou*, Risso) and saurel maxecus (*Trachurus trachurus* L.). Little decrease in salt-soluble protein content occurred after this initial period, until the end of the experiment, i.e. 8 months later. These modifications are minimal and slow with lower temperatures, and most of the denaturation occurs during the freezing process, especially if freezing is not achieved rapidly (Dyer & Dingle, 1961).

It has been shown that the maturity stage of roe influences the protein content (Vuorela *et al.*, 1979), and subsequently it should influence the viscosity. The viscosity of the samples was not significantly different ($P > 0.05$) among the various maturity stages (Table 1).

In the present study a mayonnaise-like emulsion was made with whole eggs since this type of emulsion constitutes the base of *tarama* and other products. During the emulsion formation, fat globules are mainly coated with proteins and other emulsifying agents (e.g. phospholipids) until there is not enough water in the dispersing phase (Borderias *et al.*, 1985). No significant differences ($P > 0.05$) in emulsifying capacity were noted among the various maturity stages (Table 1).

With the type of emulsion studied here, we could not determine precisely the moment when the system was 'saturated' with oil, i.e. when the emulsion broke, but the emulsion stability can give an index of the functional properties of the proteins. In the present study (Table 1), the emulsion stability was high (around 98% of the original emulsion was maintained after centrifugation) and was not affected by the maturity stage of the eggs ($P > 0.05$). Furthermore, the emulsifying capacity and the emulsion stability were positively correlated variables ($P \leq 0.010$; $n = 30$). Therefore, the more oil the eggs can maintain in emulsion, the

Table 1. Physico-chemical parameters of autumn-harvested herring roe at different stages of maturity

Stage	GSI(%)	pH	Viscosity (cps)	EC (ml/g)	ES(%)
1	$16.6^a \pm 4.9$	$5.73^a \pm 0.07$	$6609^a \pm 2205$	$3.76^a \pm 0.18$	$98.2^a \pm 1.0$
2	$12.8^b \pm 4.0$	$5.73^a \pm 0.1$	$3990^a \pm 379$	$3.43^a \pm 0.18$	$99.1^a \pm 0.2$
3	$8.6^c \pm 3.1$	$5.68^a \pm 0.3$	$5181^a \pm 748$	$3.18^a \pm 0.15$	$99.1^a \pm 0.1$

^aGSI, gonado-somatic index; EC, emulsifying capacity; ES, emulsion stability.

^bValues within a column with a similar letter are not significantly different ($P > 0.05$).

^cValues represent the mean of 10 determinations, except for the GSI (30 observations).

more stable and irreversible the emulsion is, at its breaking point.

CONCLUSIONS

In conclusion, the functional properties of herring eggs were not a function of maturity. The emulsion stability of herring eggs was high, even with an advanced stage of maturity. This is an important attribute for the manufacturing of fish egg-based products. Although blood appears on the ovary wall of the roe at the end of stage VI (spawning), the period between capture and death of the fish is critical, since the more the fish fights during netting, the more the gonads become reddish and bloody (Huynh, 1986). A suitable wash would then be sufficient to clean the eggs of debris and blood; roe discarded at the plant (i.e. stage 3) could therefore be used in the preparation of various roe products since their physical and functional properties are not different from eggs at a less advanced maturity stage.

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