Effect of Pressure on the Salting and Ripening Process of Anchovies (*Engraulis anchoita*)

BEATRIZ E. FILSINGER

ABSTRACT

The effect of pressure on the salting and ripening process of anchovies was studied. Salt and water were determined throughout the process to establish the dynamics of salt penetration. The ripening of anchovies was evaluated by means of the total ester index and sensory assessments. The best quality product corresponded to an intermediate pressure of 131.5 g/cm^2. Salt penetration and ripening was intermediate between the other two samples. Higher pressure increased salt penetration and diminished ripening velocity. These products, however, did not possess the best sensory characteristics. Lower pressure changed the ripening process and yielded an over-ripe product.

INTRODUCTION

THE PRESERVATION of foods by salting is competitive between spoilage due to tissue autolysis and microbial action and salt penetration that prevents these phenomena. Salting of anchovies can be divided into two stages: the first corresponds to the diffusion of salt into the fish and the elimination of water from it. The second stage, longer and slower than the first, is ripening which renders a product with tender consistency and the characteristic pleasant aroma and taste. During this stage the fish is stored under pressure. Due to the applied pressure a brine containing biological material is extruded and completely covers the fish. Baldrati et al. (1977) found that different pressures produce significant changes in water activity and in dry weight of anchovies (*Engraulis encrasicholus*).

The purpose of this work was to determine the dynamics of salt penetration, the ripening velocity and sensory assessments of salted and maturated anchovies, which were prepared under different pressures, while keeping constant the other variables, such as temperature, salt weight, kind of salt and raw material characteristics.

MATERIAL & METHODS

ANCHOVIES (*Engraulis anchoita*) were caught on the Argentinian platform in the south-western Atlantic Ocean from 37.4°S to 38.8°S during spring, when they arrived at the coast for spawning. After being caught, the fish were held without ice for 2 or 3 hr before they arrived at the laboratory where they were immediately immersed for one day in saturated brine at room temperature (18–22°C). The fish were then manually beheaded, partially gutted in the same operation and packed in 10 kg cans, 24 cm high and 21.5 cm diameter. To reproduce industrial conditions a collar was put around each container which contained 13 kg anchovies and 2 kg salt. A layer of salt was first put in the container then a layer of fish and so on until the container was filled with alternate layers of salt and fish finishing with a layer of salt. A piece of wood (1 cm high and 21.5 cm diameter) was placed on the top layer of salt. By means of concrete stones on top of the wooden discs the fish were pressed. The pressure was calculated as the quotient of total weight on the disc by the surface area of the container. The cans were divided into three lots of 18 cans (A, B and C) with the following pressures: A, 65.8 g/cm^2; B, 131.5 g/cm^2; C, 197.4 g/cm^2. Cans were stored for ripening in a room at 18–22°C for 300 days.

Anchovies for chemical analysis were selected from the middle of the can. Anchovies were filleted and passed through a home meat mincer. All chemical tests were done in duplicate. Determination of salt was performed according to the AOAC (1960) method based on titration with silver nitrate. Water was determined by weight lost after 24 hr at 105 ± 1°C (Boeri et al., 1978). Apparent water activity values were calculated by means of the equation $a_w = 1.002 - 0.042m$ proposed by Lupín et al. (1981), where m is the NaCl molality considered to be in true solution in the total water content of the product. Total ester index was determined by a modification of the AOAC method (Filsinger et al., 1982). Ten grams anchovies were ground in cooled distilled water in a Virtis homogenizer and made up to 100 ml. Aliquots of 20 mL were placed into distilling flasks. Into each flask was added ca. 1 ml phenolphthalein and the contents titrated to pink using 0.5 N KOH. An additional 25 mL 0.5N KOH was placed in each solution, the sample was refluxed for 1 hr, and the excess alkali was titrated with 0.1N HCl. Since the measurements were done in aqueous homogenates instead of purified lipid extracts, the values obtained are representative of total ester indices. Results were expressed in grams KOH on a corrected dry weight (CDW) basis. Corrected dry weight was calculated by subtracting the salt content from the dry weight. In the figure where total ester index vs time is plotted, the slope of the straight line is the ripening velocity. Total ester index remained constant following ripening, i.e., it had a zero slope (Himmelblau, 1970). The intercept of both lines is the ripening time.

Sensory assessments

Sensory scores were assigned according to the scoring method presented in previous work (Filsinger et al., 1982). The attributes considered were flavor, flesh color, odor, flesh consistency and flesh adherence to the backbone. The anchovies were sensorily evaluated by a panel of six people experienced in judging fish quality. The judges were previously trained in the fish processing industry according to the current methods used to assess the degree of ripening of salted anchovy. A scale of points from 0 to 8 replaced the ambiguous "unripe" or "green", "ripe" and "over-ripe" terms which are traditionally used by expert tasters in the fish processing industry. A fish is assigned a score for each attribute according to the descriptions in the table. The average of the five attributes was taken as the score for the fish. The final score given to the sample was the average of thirty six specimens evaluated by the six judges.

RESULTS & DISCUSSION

Salting process

Figure 1 shows the changes in salt content (x_s), water content (x_w) and apparent water activity during salting for cans of lot B.

Figures 2 and 3 show the changes in salt and water, respectively, for the different lots. The fish with the highest pressure reached equilibrium faster, attaining the highest salt and lowest water content.

The following mathematical model proposed by Zugarramurdi and Lupín (977) was used to explain the salting process.

$$\frac{dx_s}{dt} = k_s \quad (x_s^* - \quad x_s) \qquad (1)$$

$$\frac{dx_w}{dt} = k_w \quad (x_w^* - x_w) \qquad (2)$$

Author Filsinger is affiliated with Instituto Nacional de Tecnología Industrial, Centro de Investigaciones de Tecnología Pesquera (CITEP), Marcelo T. de Alvear 1168, 7600 Mar del Plata, Argentina.

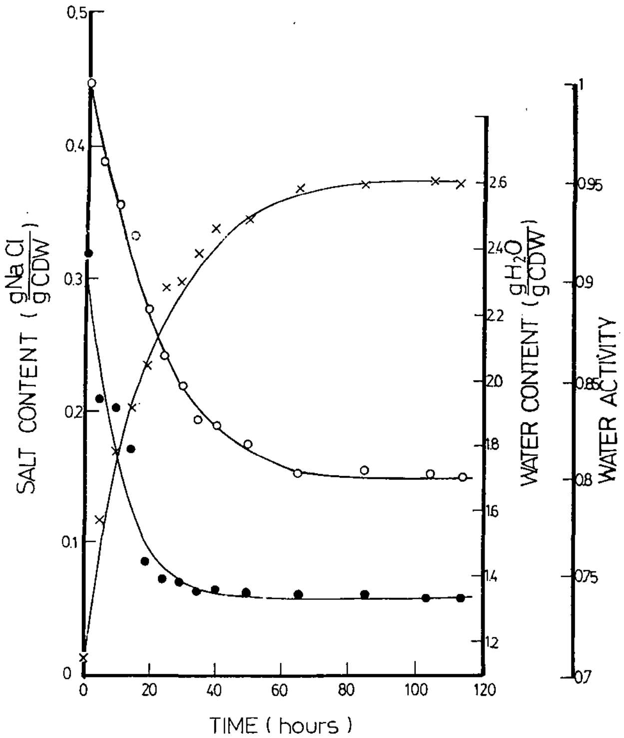

Fig. 1—Changes in salt, water and water activity during ripening of anchovies. x- - -x, salt content; ●- -●, water content; ○- - -○, water activity. CDW-corrected dry weight calculated by subtracting the salt content from weight obtained by drying.

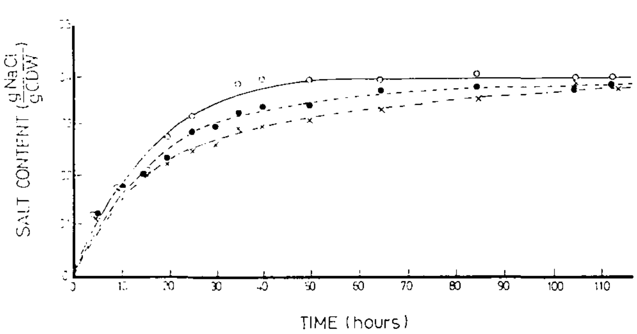

Fig. 2—Changes in salt during ripening of anchovies. Pressure: Lot A, 65.8 g/cm², -·-·-·-; Lot B, 131.5 g/cm², - - - -; Lot C, 197.4 g/cm², ———.

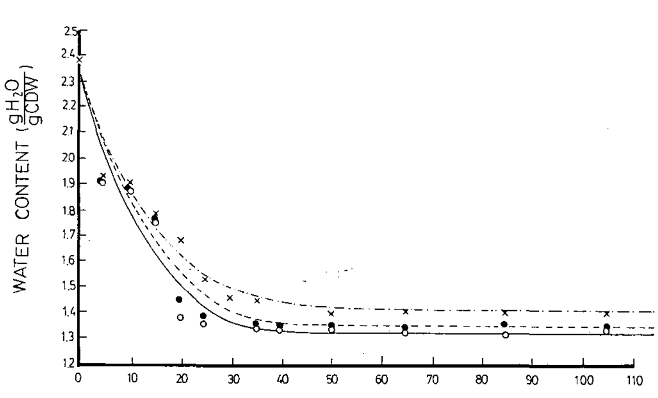

Fig. 3—Changes in water during ripening of anchovies. Pressure: Lot A, 65.8 g/cm², -·-·-·-; Lot B, 131.5 g/cm², - - - -; Lot C, 197.4 g/cm², ——.

where

$$x_s = \frac{\text{Mass of salt at a given moment}}{\text{Total mass - mass of water - mass of salt}} \qquad (3)$$

$$x_w = \frac{\text{Mass of water at a given moment}}{\text{Total mass - mass of water - mass of salt}} \qquad (4)$$

Total mass - mass of water - mass of salt is the CDW; t is the time; k_s and k_w are the specific rate constants for the variations of salt and water, respectively. The "*" values are at equilibrium.

Eq. (1) and (2) can be easily integrated with the following initial conditions

$$(t=0): \quad x_s(0)=x_s^o \quad \text{and} \quad x_w(0)=x^o_w \qquad (5)$$

The solutions are:

$$x_s = x_s^o \cdot e^{-k_st} + x_s^* (1-e^{-k_st}) \qquad (6)$$

$$x_w = x_w^o \cdot e^{-k_wt} + x_w^* (1-e^{-k_wt}) \qquad (7)$$

In order to study the correlation between experimental data and theoretical expression (6) and (7), the integral method of Swinbourne (1960) and Mangelsdorf (1959) was used. This method basically consists in a transformation of exponential expressions into a linear one, using the time interval (T) between two consecutive experimental determinations. The following expression relates the salt concentration at time (t+T) to the value at time t:

$$x_s(t+T) = x_s^* (1-e^{-k_st}) + e^{-k_sT}. x_s(t) \qquad (8)$$

A similar expression can be obtained for $x_w(t+T)$ in terms of $x_w(t)$.

According to Eq. (8) the plot of $x_s(t+T)$ against $x_s(t)$ is a straight line, where the first term of the second member is the y-intercept and e^{-k_sT} is the slope. The values of $x_s(t+T)$ against the corresponding $x_s(t)$ values for lot B are plotted in Fig. 4. From the slope of the linear it was possible to calculate k_s. The values of k_s and k_w for the three lots calculated in a similar way are presented in Table 1. The correlation coefficients and the 95% confidence limits are also given. The results showed higher values of k_s and k_w when pressure increased. Moreover, the highest increases of dry weight (or lowest water) and the highest salt were found in the anchovies from lot C. The fastest decrease of apparent water activity was observed for lot C (Fig. 5). For equal amounts of added salt higher pressures produced lower apparent water activities.

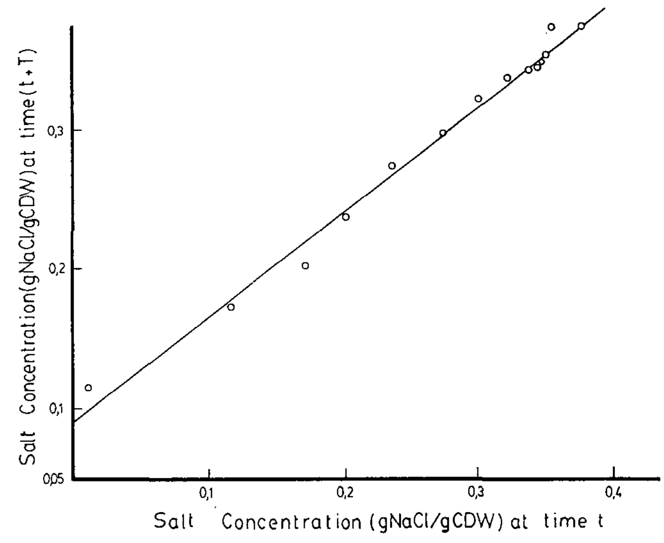

Fig. 4—Relation of salt concentration at time, (t+T), to salt concentration at time t for lot B.

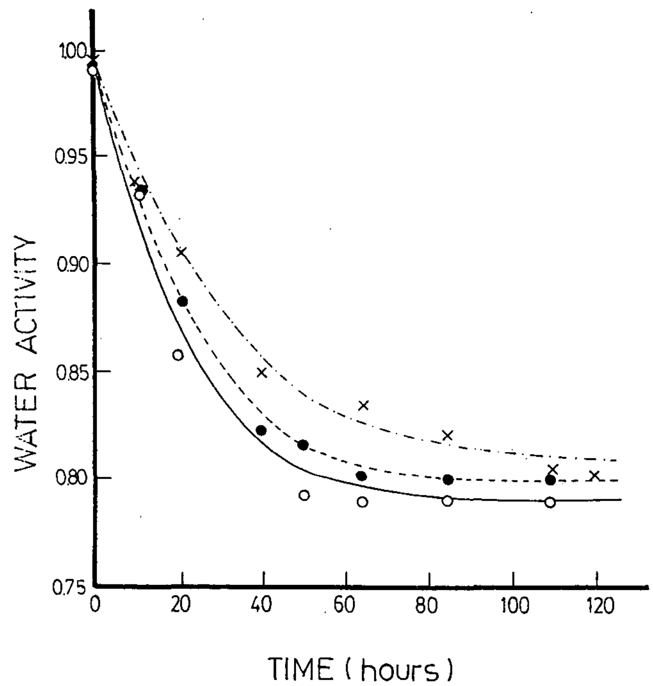

Fig. 5—Changes in water activity during ripening of anchovies. Pressure: Lot A, 65.8 g/cm², -·-·-; Lot B, 131.5 g/cm², - - -; Lot C, 197.4 g/cm², ———.

Table 1—Values of the specific constants and confidence limits for 95% probability for pressure-processed anchovies

	Salt		Water	
Sample	k_s (hr^{-1})	r	k_w (hr^{-1})	r
Lot A[a]	0.06732 ± 0.008	0.99	0.08474 ± 0.005	0.96
Lot B[b]	0.07318 ± 0.010	0.97	0.09015 ± 0.007	0.94
Lot C[c]	0.08727 ± 0.006	0.98	0.10337 ± 0.008	0.92

[a] 65.8 g/cm² pressure
[b] 131.5 g/cm² pressure
[c] 197.4 g/cm² pressure

Ripening process

Figure 6 shows the results of total ester index vs time for lots A, B and C. The slope of the straight line is the ripening velocity. Total ester index remained constant during the storage after complete ripening. The intercept of both lines is the ripening time.

Figure 7 shows the results of sensory scores vs time. The ripening times evaluated by means of sensory scores approximately agreed with those determined by means of the total ester index.

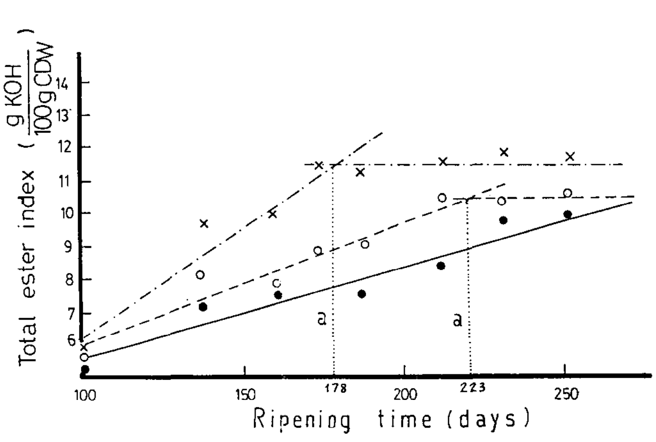

Fig. 6—Changes in Total Ester Index during ripening of anchovies. Pressure: Lot A, 65.8 g/cm², -·-·-; Lot B, 131.5 g/cm², - - - -; Lot C, 197.4 g/cm², ———.[a] Intercepts indicate complete ripening time.

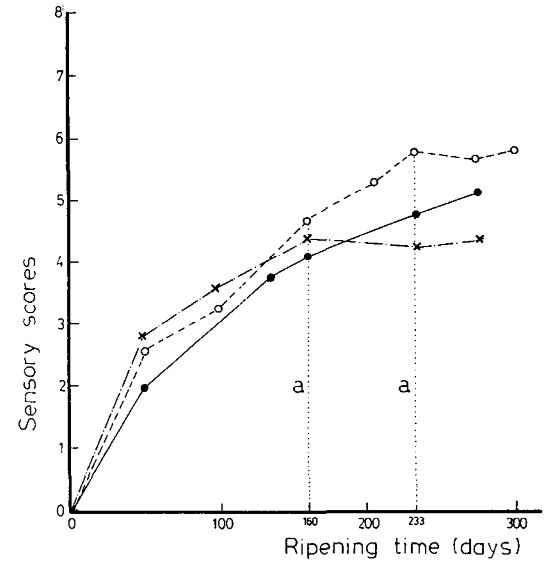

Fig. 7—Sensory scores of anchovies at various periods of ripening. Each point is representative of at least 36 samples and is the average of the sensory characteristics evaluated according to the scoring method presented in previous work (Filsinger et al., 1982). Pressure: Lot A, 65.8 g/cm², -·-·-; Lot B, 131.5 g/cm², - - - -; Lot C, 197.4 g/cm², ———. Sensory scores: 0, raw fish; 2, beginning of ripening; 4, the middle stage; 6, complete ripening; and 8, deteriorated or over-ripe anchovy. Odd numbers were reserved for intermediate stages. [a]Intercepts indicate complete ripening time.

Table 2—Ripening velocity and time of ripening for pressure processed anchovies

Sample	Ripening velocity by TEI method (gKOH/100g[a] day)	Time of ripening by TEI method (days)	Time of ripening by sensory scores (days)
Lot A[b]	0.06726	178	160
Lot B[c]	0.03757	223	233
Lot C[d]	0.02884	>254	>280

[a] On corrected dry weight basis
[b] 65.8 g/cm² pressure
[c] 131.5 g/cm² pressure
[d] 197.4 g/cm² pressure

Ripening velocity and ripening time for the three lots are presented in Table 2. The results showed that the ripening process was slower when pressure was increased.

Anchovies of lot C never reached ripening, so flesh completely lacked elasticity, and the backbone adhered very tightly to the flesh which was torn in the filleting process. There was no uniformity in color which showed dark red blots. Very little pressure (lot A) yielded an over-ripe product which was characterized by: flimsy flesh which tore in the filleting process; color was uniform and odor was lightly rancid. The best quality anchovies obtained in this work were those of lot B, where color was uniform, flesh was firm and resistant and separated neatly from the backbone with the characteristic flavor of ripened anchovies.

CONCLUSION

HIGHEST PRESSURE lowered the ripening velocity but accelerated the penetration of salt. This faster salt penetration decreased water activity and inhibited bacterial growth more rapidly, but this product did not possess the best sensory characteristics. Very little pressure changed the maturation and yielded an over-ripe product. —Continued on page 927