Journal of Tokyo University of Fisheries, Vol. 81, No. 2, pp. 155–159, December 1994

NONDESTRUCTIVE TESTING OF CONGESTION OF BLOOD IN SALMON BY ULTRASONIC*

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The ultrasonic nondestructive test procedure was applied to detect the congestion of blood in the salmon meat which was supplied as the raw material of smoked salmon. For the thawed salmon fish meat, the echo pulses from the defect portion could be separated from the normal reflection from the backbone or the skin. On the contrary, for the frozen salmon meat, the ultrasonic acoustic wave could not transmit into the fish meat. This phenomena indicated that the very complex boundary which were made from the micro ice crystal granular reflected the ultrasonic wave in various directions, so the reflected ultrasonic wave could not return to the probe of transducer.

Key word: nondestructive testing, ultrasonic test method, frozen fish meat, thawing, smoked salmon

Introduction

In general, smoked salmon is made from the thawed whole fish meat which is imported from Canada, Alaska and other countries to Japan. Sometimes, a congestion of blood in the products is detected after they are sliced for the consumption. Therefore it is necessary to remove the raw salmon which has been damaged inside prior to smoking. From the point of processors, the selection of the salmon having been congested from the normal ones is preferred to be done while the raw materials are frozen. Very skilled workers can pick up the damaged one even after thawing, but the number of these trained persons becomes limited these days.

In this work, the ultrasonic nondestructive testing method was attempted to apply for detecting the congestion of blood in the salmon bodies which were frozen or thawed. The application of ultrasonic nondestructive system for evaluating the quality or the faults of food has not been carried out intensively (1, 2, 3). The system used in this work was the standard nondestructive system which is very popular for evaluating the welding condition of metal. The application of ultrasonic for evaluating the quality of sea food has not been developed. According to the medical reports (4), ultrasonic testing procedure has been employed to diagnose the inflammation of the liver.

Theoretical background

When acoustic waves pass through the boundary which is between the different acoustic impedance materials, they reflect or pass through at the boundary depending on the acoustic impedance ratio. The acoustic impedance is defined as the sound velocity (c) multiplied by the density of material (ρ); $W=c\times\rho$. Let a sound travel from a material 1; c_1, ρ_1 to a material 2; c_2, ρ_2. The

* Received May 31, 1994.

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Table 1. Characteristic impedance.

Solid/Liquid	Density kg/m^3	Sound velocity m/sec	Impedance kg/sec/m^2
Ice	920	3200	2.95×10^6
Water	998	1500	1.48
Brain	1038	1530	1.59
Muscle	1040	1568	1.63
Bone	1800	3700	6.66

impedances of material 1 and material 2 are W_1 and W_2, respectively. If the ratio of impedance of material 1 to 2, W_1/W_2, is nearly equal one, the acoustic waves pass through the boundary without reflection. On the contrary, if the ratio is less than one or larger than one, the acoustic waves reflect at the boundary. The intensity of the reflected waves depends on the differences of impedance of materials. The differences become large, the intensity of reflection become high, after the acoustic wave reflects at the boundary (5).

The acoustic impedances of various materials have been measured and are cited in the Table 1. Differences of them are not so much except the bone's. But, these small differences are detectable by the ultrasonic nondestructive test methods.

Materials and Methods

Sockeye salmon (Oncorhynchus nerka), which was stored frozen and imported from Canada, was used in this experiment. Specimens were used in frozen or thawed condition.

A conventional nondestructive ultrasonic metal testing system (Mitsubishi Electric Co., FD-410) was used with a sensor probe (Panametrics Inc. V106). This testing system can detect 3 mm thick steel plate with 5 MHz testing wave and measure the length from 9.2 mm to 4.2 m. Out put pulse for measurement repeats by 50 Hz at test range 5, but this repeating cycle relates to the test range. The efficiency of this instrument is tunable to 90 dB. This probe, which was 12 mm diameter and made of ceramics, was a broad band type having 2.37 MHz center frequency and the upper frequency was 3.40 MHz and the lower frequency 1.34 MHz. This worked as the transmitter and the receiver in a sequence.

The schematic measurement procedure is shown in Fig. 1. The probe was fixed on the specimen

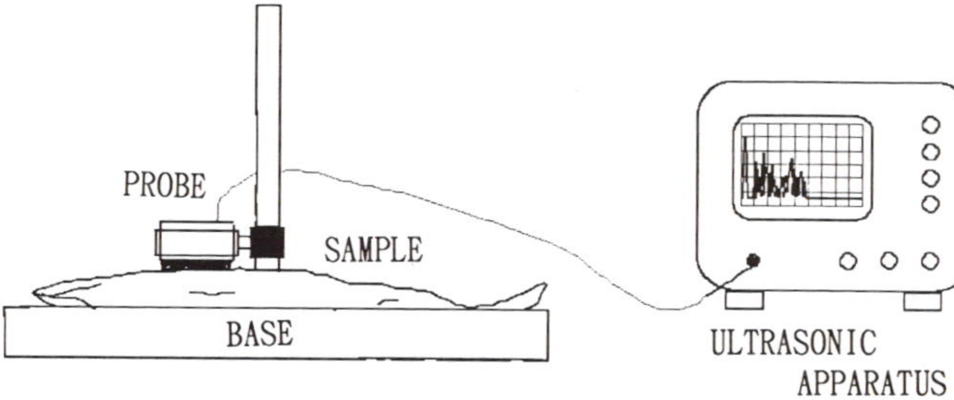

Fig. 1. Schematic diagram of apparatus.

from upper side. Glycerin was used as the lubricator between the fish skin and the probe surface. By using this lubricator, the ultrasonic can be transmitted from the probe to the sample without attenuating by air layer between them.

Prior to the experiments, the time axis or the distance axis of the ultrasonic apparatus was calibrated by measuring the sound velocity of the Lucite which was 1500 m/s. Oscillograms of the reflected ultrasonic echo pulses were recorded by photos.

Results and Discussions

1) Evaluating a thawed meat

The probe was set on the skin of salmon and the pulse echoes of ultrasonic from the inside were recorded (Fig. 2A and Fig. 2B). In Fig. 2A, the echo pulse numbered 1 was reflected from the backbone of salmon and the number 2 pulse from the skin of the other side. While in Fig. 2B, the number 1 pulse from the backbone could be detected but the number 2 echo pulse from the skin was undetectable. This means that there were lots of echo pulses between the incident pulse and the echo pulse from the backbone. These pulse intensities were higher than that those (Fig. 2A) and so they were considered to be produced from a defect which was in the meat between the skin and the bone. The intensity of reflected ultrasonic wave was decreased by this defect, so the reflected echo pulse from the skin of the other side became vague and was undetectable. The fish meat which gave the reflected pulses from the defects was shown in Fig. 3. There was dark red colored protion observed between the skin and the backbone. These damaged portions seemed to reflect the acoustic wave. The texture of meat at this portion was soft and loose. blood or drip was exuded from this portion while thawing. It seemed that this part were, if anything, more soft than another part.

The whole fish meat was cut into a block at the right angle to the backbone. The probe was set on the surface of the cross section of this fish meat block. Their oscillograms are given in Figs. 4A and 4B. An incident pulse and a reflected echo pulses from the other side of the cross section were detected (Fig. 4). There were also other pulse echoes between them. In Fig. 4B, there were pulses between the

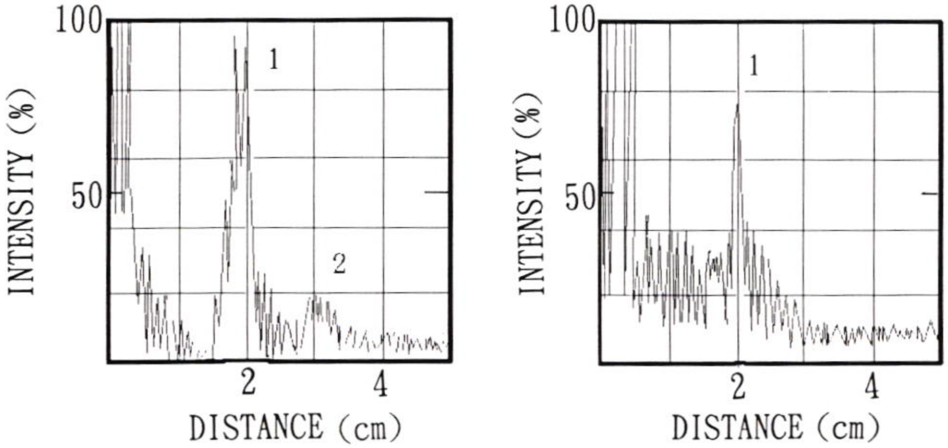

Fig. 2. Oscillogram of ultrasonic echo pulse detected from the fish skin.
A: Echo pulse from normal fish meat. Pulse 1 is the backbone and 2 is the skin of other side. B: Echo pulse from the fish meat having the defects. Pulse 1 is the backbone and there are high intensity pulses between the incident and backbone.

Fig. 3. The cross section of the salmon meat specimen. The dark red part was the congestion of blood.

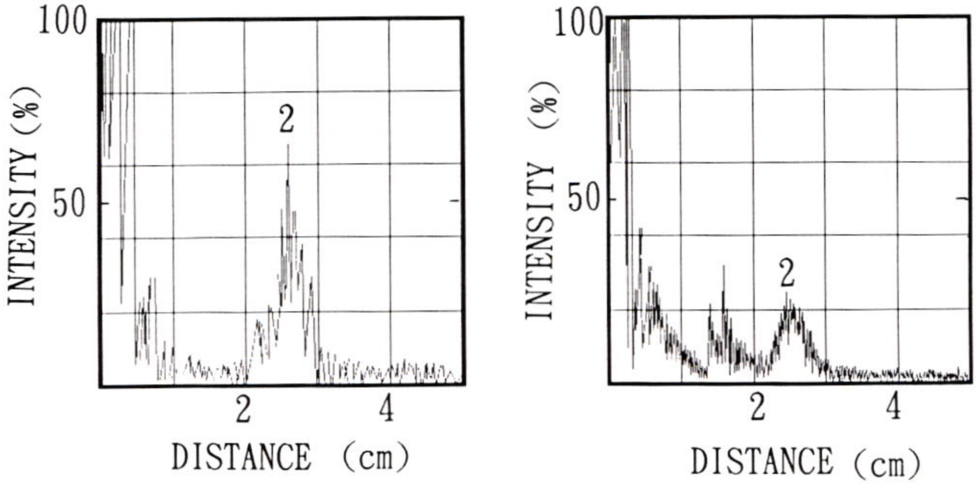

Fig. 4. Oscillogram of ultrasonic echo pulse detected from the cross section of the fish meat specimen.

A: Echo pulse from the normal fish meat. B: Echo pulse from the abnormal fish meat.

incident pulses and the pulse from the opposite cross section of meat. These echo pulses were produced from the defected portion of meat.

2) Evaluating a frozen meat

The probe was set on the fish body as the same way mentioned above. The oscillogram from this specimen showed only the incident pulses from the probe. The reflect pulses from the backbone and the skin of another side did not appeared in the oscillograms. It was considered that the micro ice crystal grains which grew in the meat during freezing process became vigorous reflector to the acoustic waves. The ultrasonic was reflected from the micro ice crystals' boundaries located near the fish skin, immediately after it was transmitted. As the frozen fish meat was thawed, the echo pulses from the boundary between unfrozen and frozen meat appeared and moved from the surface side to inside by the thawing process proceeding.

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超音波によるサケ魚肉の非破壊検査

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スモークサーモンの原料となるベニザケには冷凍輸入品が多く用いられている。しかし，時としてこれらの原料魚には，漁獲直後に受けたなんらかの要因により魚体内部にうっ血していることがあり，この様な原料からの製品は格外品となる。

本研究では金属用の超音波探傷器を用い，魚体内部に生じたうっ血部位を非破壊的に探索することを試みた。解凍後の魚体では，超音波を表皮から照射した場合，背骨からのエコー以外に，うっ血部からの多数のエコーを確認することができたが，凍結魚体については超音波が表面近傍の氷結晶から強く反射するため，内部を探索することはできなかった。

キーワード：非破壊検査，超音波探傷器，凍結魚肉，解凍，スモークサーモン