Observations From a Preservation and Processing Study on Atka Mackerel, *Pleurogrammus monopterygius*

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Introduction

The Gulf of Alaska and the Bering Sea contain some of the world's most abundant fishery resources. In recent years, catches of more than 2 million metric tons of groundfish have been landed, primarily by foreign fleets (Nelson and Miyauchi[1]). This fishery is basically composed of walleye pollock, *Theragra chalcogramma*; Pacific cod, *Gadus macrocephalus*; Pacific ocean perch, *Sebastes alutus;* yellowfin sole, *Limanda aspera*; and several other species including Atka mackerel, *Pleurogrammus monopterygius* (Fig. 1), of the greenling family (Hexagrammidae). Although less abundant than other species, Atka mackerel are nonetheless an important resource to foreign fishermen currently fishing Alaskan waters.

Kizevetter (1973) reports that Atka mackerel is considered the most important fish, in terms of food value, of the ten species from the family Hexagrammidae that are commercially fished by the Soviets. Japan began a large-scale commercial fishery for *Pleurogrammus azonus*, a species of greenling very similar to Atka mackerel, in Hokkaido waters in the 1950's. Thus, with the advent of the foreign groundfish fishery in Alaskan waters, Atka mackerel have also become a significant part of that fishery. Atka mackerel are extensively fished by Japan, Russia, and Poland off Kodiak Island and the Aleutian chain (Macy et al.[2]). Fishing activities are usually conducted from June to September when Atka mackerel move from the offshore to the onshore waters preparatory to spawning (Larkins, 1964).

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[1]Nelson, R. W., and D. Miyauchi. 1976. Preservation and quality characteristics of Alaska bottomfish and tests on minced pollock flesh. Natl. Mar. Fish. Serv., NOAA, Northwest Alaska Fish. Cent., 2725 Montlake Boulevard East, Seattle, WA 98112. Processed rep., 2 p.

[2]Macy, P. T., J. M. Wall, N. D. Tampsakis, and J. E. Mason. 1978. Resources of non-salmonid pelagic fishes of the Gulf of Alaska and Eastern Bering Sea. Natl. Mar. Fish. Serv., NOAA, Northwest Alaska Fish. Cent., 2725 Montlake Boulevard East, Seattle, WA 98112. Processed rep., 311 p.

ABSTRACT—Chemical composition, physical and sensory characteristics, and processing yields were determined on frozen whole and butchered (heads off) Atka mackerel, Pleurogrammus monopterygius. *In addition, two methods of thawing Atka mackerel were compared. Canned products made from the Atka mackerel were evaluated organoleptically, and process yields were determined. The effect of seasonal variation on proximate composition, mineral content, and sensory characteristics was also determined. Taste panel evaluation results indicate that both fresh and canned products produced from frozen Atka mackerel were of high quality and very acceptable.*

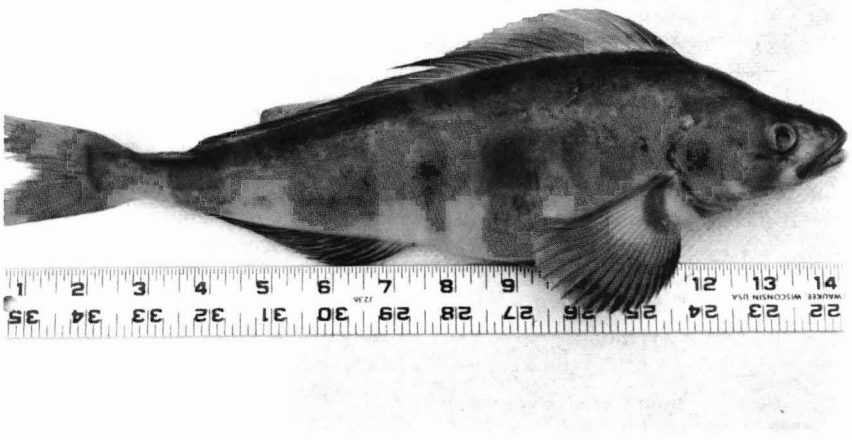

Figure 1.—Adult Atka mackerel, *Pleurogrammus monopterygius.* Photo by William L. High, NMFS Northwest and Alaska Fisheries Center, Seattle, Wash.

In 1982, the foreign fishery allocation for Atka mackerel was about 45,000 metric tons, or nearly 20 percent of the total foreign groundfish allocation in Alaska (Hasselback, 1982). Although Atka mackerel are fished by U.S. fishermen in joint ventures with foreign countries, they are otherwise of little value to U.S. fishermen because domestic markets have not yet been developed.

The Utilization Research Division of the NMFS Northwest and Alaska Fisheries Center has evaluated Atka mackerel as a possible resource for exploitation by our domestic fisheries. Although information concerning biological and ecological aspects of Atka mackerel is available, little research has been reported in the literature on the commercial usefulness of this species. Therefore, the focus of the research reported here was directed toward obtaining information concerning fillet yields, sensory attributes, and chemical composition of the frozen and canned products.

Materials and Methods

Fish Samples

The fish samples were caught in the vicinity of Albatross Bank southeast of Kodiak Island in September of 1979 by the Soviet fisheries research vessel *Poseydon* working jointly with American fisheries scientists (Reppond[3]) and in February of 1980 by the NOAA research vessel *Miller Freeman*. The September catch was frozen in 10 kg blocks, whereas the February catch was individually quick-frozen and glazed prior to boxing and shipping to the laboratory for analysis and evaluation. Due to vessel operations and delays in shipping fish from Alaska to Seattle, laboratory analyses were begun 2½ months after the September catch and 4 months after the February catch.

[3]Reppond, K. D. 1979. Preliminary report on experiments on Atka mackerel on the USSR R/V *Poseydon*, Kodiak Invesgitations-Utilization, Northwest and Alaska Fisheries Center, NMFS, NOAA, Kodiak, AK 99615. Tech. Rep. 119, 4 p.

Sample Preparation and Procedures

To determine fillet yields, fish were thawed at 34°F, weighed, measured, and then hand filleted. Fillet yields were calculated on the basis of whole and headed and gutted (H&G) fish weights. Because fillet yields were determined on the freshly landed Atka mackerel caught by the R/V *Poseydon* in September (footnote 3), they were not redetermined in this study.

To determine changes in the quality of fish held in frozen storage under accelerated temperature conditions, fish samples from the February catch were packed in master cartons lined with 1.5 ml polyethylene bags and stored at 0°F. At regular intervals of 1, 2, and 3 months, fish from each treatment were analyzed for thaw and cooked drip, oxidative rancidity (TBA value) protein in thaw drip, and sensory attributes.

To determine the effects of seasonal variation on chemical composition and mineral content, the edible flesh from 10 fish each of the September and February catches was analyzed for moisture, protein, fat, ash, and various minerals.

Raw, steamed, and smoked Atka mackerel fillets were portioned and packed in 0.5-pound (307 × 200.25) cans. Water, salt, broth, or oil were added to some cans for flavor enhancement. Each can contained about 6 ounces of meat. The cans were vacuum sealed and thermally processed at 242°F (10 psi) for 75 minutes, water cooled, and stored at 34°F until evaluated.

Process recommendations for canned Atka mackerel have not yet been established. The smoked samples were prepared as follows: Fish fillets were brined in an 18 percent NaCl solution for 10 minutes, rinsed lightly in fresh water, and drained for 10 minutes. The brined fillets were placed in a smokehouse and heated to 75°F for 1 hour in the presence of light alder smoke followed by additional heating at 120°F with light smoke for 1 hour, and final cooking at 175°F in the presence of heavy alder smoke for 30 minutes. The smoked fillets were then portioned to size and packed in 0.5-pound cans and thermally processed as previously described.

Analytical Methods

Analyses for moisture, fat, and ash were determined according to AOAC methods (Horowitz, 1980). The total Kjeldahl nitrogen method described by Taras et al. (1971) was used to determine protein in the fish. Protein in the thaw drip was analyzed according to the AOAC micro-Kjeldahl method (Horowitz et al., 1975). Mineral content, except for mercury, was determined by emission spectroscopy (Teeny et al., 1984). Mercury was determined by the Official Food and Drug Administration Vanadium Pentoxide Method (Horowitz, 1980). Chemical determinations for oxidative rancidity were done according to the method of Lemon (1975).

Comparative thaw and cooked drip determinations were made on ½-inch thick steaks with viscera and belly flaps removed. Two different methods of thawing the frozen samples were evaluated. The drip from each method of thawing was saved for protein analysis. In the first method, frozen steaks were weighed, placed on trays enclosed in plastic bags to minimize dehydration, and allowed to come to a soft-frozen state at ambient temperature. The samples were then held overnight at 34°F, drained, and reweighed. Samples thawed by the second method were weighed and placed in the inner pouch of a double plastic pouch arrangement, in which the inner pouch, containing the sample, was perforated to permit removal of drip from the sample and the outer pouch to collect the drip. The samples were then placed in a water bath at 68°F for 2 hours, drained, and reweighed. Cooked drip was determined by weighing ½-inch thick frozen steaks in aluminum containers with covers and baking at 375°F for 15 minutes, draining over a number 8 sieve for 10 minutes, and reweighing. Drained weights of the canned products were estimated by

draining samples over a number 8 sieve for 5 minutes. The oil content was determined volumetrically.

Sensory Tests

Fish samples prepared for cooked drip analysis were used to make the sensory evaluations. Samples were evaluated by a taste panel for flavor, texture, and sensory rancidity using a 5-point numerical scale. Similarly, the panel rated the canned products for the same attributes, but also included a 9-point hedonic scale to determine product acceptability.

Results

Fillet Yields and Chemical Composition

Results of the analysis for fillet yields (Table 1) are based on class length and weights and represent both whole and H&G Atka mackerel from the February catch. The data show that the yields were not dependent on the length or weight of the fish. Linear regression plots with corresponding correlation coefficients in Figures 2 and 3 show that the Atka mackerel caught in September were about twice as heavy as those caught in February (48.4 vs. 25.0 g/cm). The apparent difference in the weight of the September catch relative to the February catch reflects the state of sexual maturity of the fish and is attributed to an increase in the fat content of the flesh and growth of the internal organs including gonads. The fillet yield from the fall (September) caught fish would be expected to be less than the yield from the winter-caught (February) fish. Kizevetter (1973) made similar observations on *P. monopterygius* caught in Peter the Great Bay and in the Bering Sea. In joint research with Russian fishery scientists aboard the U.S.S.R. R/V *Poseydon*, Reppond (footnote 3) observed that the average fillet yield from hand-filleted whole Atka mackerel caught in the vicinity of Albatross Bank southwest of Kodiak Island in September 1979 was 29 percent. The reduced yield (compared with the recovery of edible product from the February-caught fish) was attributed to the well developed gonads of the fish, particularly the females, indicating that spawning was imminent.

Chemical analyses of the edible flesh from both catches show that fish caught in September were significantly ($P = 0.05$) higher in fat content and lower in moisture than fish caught in February (Table 2). Fujii

Table 1.—Fillet (skin off) yields from whole and H&G Atka mackerel caught in February.

Whole fish					Headed and gutted fish				
Length class (cm)	Number of fish	Whole weight (g)	Fillet weight (g)	Fillet yield (%)	Length class (cm)	Number of fish	Whole weight (g)	Fillet weight (g)	Fillet yield (%)
28	2	256	106	41.41					
29	1	298	106	35.57	24	4	252	134	53.17
30	1	383	151	39.43	25	6	268	134	50.00
31	7	371	147	39.62	26	9	304	163	53.62
32	12	402	163	40.55	27	5	346	167	48.26
33	10	411	153	37.23	28	5	312	157	50.32
34	3	402	161	40.05	29	8	314	166	52.87
35	6	412	159	38.59	30	5	317	186	58.68
36	2	520	217	41.73	31	1	349	195	55.87
Average 32.5		384	151	39.3	27.2		300	163	52.9

Table 2.—Proximate composition and sensory attributes of the edible flesh of Atka mackerel caught in September and February.

	Number of	Proximate composition (%)				Sensory attributes[1]		
Catch date	fish	Moisture	Protein	Fat	Ash	Flavor	Texture	Rancidity
September	10	73.7 ± 2.1	17.4 ± 1.5	6.4 ± 1.7	1.3 ± 0.2	4.5 ± 0.5	4.5 ± 0.8	4.1 ± 0.9
February	10	79.0 ± 1.3	17.5 ± 0.8	2.3 ± 1.2	1.2 ± 0	4.2 ± 0.4	4.8 ± 0.4	4.2 ± 0.8

[1] Scale of 1-5 with 5 indicating a fish with good flavor, normal (firm) texture, and no rancidity.

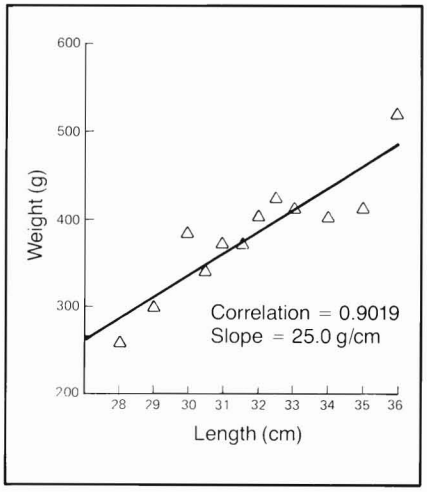

Figure 2.—Length/weight regression plot for whole Atka mackerel, February 1980.

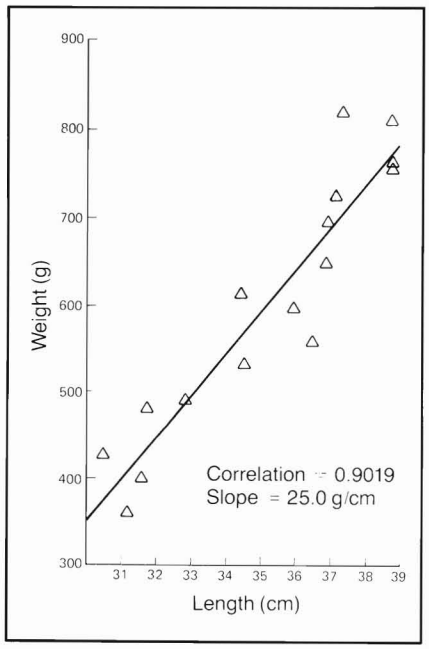

Figure 3.—Length/weight regression plot for whole Atka mackerel, September 1979.

(1954) and Kizevetter (1973) found that the fat content of Atka mackerel is at its highest during the prespawning period from May through October depending on fishing areas. There was no difference between the protein content of the September-caught fish and the protein content of fish caught in February.

The mean metal concentration of the elements is presented in Table 3. Analysis of data by the Student *t* test showed that the September catch contained significantly higher levels of copper, potassium, and sodium than the February catch. For the remainder of the elements, no significant differences were found between the two catches.

Table 3.—Mineral composition of Atka mackerel fillet muscle caught in September and February southeast of Kodiak Island.

Mineral	Composition (μg/g) September catch	February catch
Ca	143 ± 31.9	161 ± 50
Cr	0.134 ± 0.036	0.109 ± 0.011
Cu	0.797 ± 0.107	0.489 ± 0.034
Fe	7.44 ± 1.41	5.07 ± 1.12
Hg	0.016 ± 0.002	0.012 ± 0.004
K	5,210 ± 180	1,780 ± 201
Li	0.029 ± 0.004	0.116 ± 0.014
Mg	292 ± 16	303 ± 16
Mn	0.123 ± 0.012	0.099 ± 0.019
Na	650 ± 109	385 ± 34
P	2,700 ± 82	2,440 ± 66
Sr	0.338 ± 0.107	0.295 ± 0.107
Zn	4.42 ± 0.59	5.72 ± 0.52

Frozen Storage Studies

The quality of whole and H&G Atka mackerel remained good throughout the 3 months of frozen storage (Table 4). Mean flavor scores decreased from 4.2 for whole and H&G fish to 3.2 and 3.5, respectively. Texture remained almost unchanged throughout the 3 months of frozen storage. Similarly, no significant changes were observed in sensory rancidity scores as a result of treatment or time in storage.

Results of chemical analyses for oxidative rancidity (TBA value, Table 4) indicated no significant changes in rancidity during the first 2 months of frozen storage in the laboratory. However, a significant and unexplained increase in TBA values was observed after 3 months of frozen storage. At this time, the samples had been frozen for a total of 7 months (3 months in the laboratory plus 4 months aboard the R/V *Miller Freeman*). The increase in TBA values indicated a potential rancidity problem not detected by the taste panelists.

Data showing the effect of frozen storage on the formation of thaw and cooked drip in steaks cut from fish stored at 0°F for 1, 2, and 3 months are presented in Table 5. These data show that fish thawed at 34°F produced slightly less than half of the amount of drip as that produced by fish thawed at 68°F (average combined thaw drip for whole and H&G fish at 34° and 68°F, respectively, was 2.8 percent and 5.4 percent). Because only small differences were observed in the amount of thaw drip between the whole and H&G fish samples within each thaw temperature group (34°F vs. 68°F), we can assume that time in frozen storage in this experiment did not play a significant role in the process of thaw drip formation. Miyauchi et al. (1962) reported that the formation of thaw drip in Pacific cod was dependent on storage temperature and time. Cooked drip data show a slight decrease in drip with storage time, but there was no significant difference in the amount of cooked drip from the whole and H&G fish.

Protein content in the drip from samples thawed at 34°F and 68°F are presented in Table 6. The content of protein in the drip of the samples thawed at 34°F was slightly greater than the protein content in the samples thawed at 68°F. The differences in protein content, however, appeared to be related more to the methods of thawing than to the experimental storage conditions. Differences in protein content in the drip

Table 4.—Sensory[1] and chemical evaluations of Atka mackerel caught in February and held in frozen storage for 3 months.

Laboratory storage time[2] (months)	Form	Flavor	Texture	Rancidity	TBA (μmoles malonaldehyde/100 g fillet muscle)
0	Whole fish	4.2 ± 0.4	4.8 ± 0.4	4.2 ± 0.8	0.29 ± 0.07
	H&G	4.2 ± 0.6	4.8 ± 0.4	4.5 ± 0.8	0.22 ± 0.05
1	Whole fish	3.5 ± 0.6	4.8 ± 0.5	4.5 ± 0.6	0.04 ± 0.02
	H&G	4 ± 0.8	4.5 ± 0.6	4.8 ± 0.5	0.13 ± 0.02
2	Whole fish	3.2 ± 1.1	4.3 ± 1.1	3.7 ± 1.4	0.19 ± 0.04
	H&G	3.5 ± 0.6	4.2 ± 1.1	4.6 ± 0.6	0.40 ± 0.36
3	Whole fish	3.2 ± 0.9	4.8 ± 0.5	4.2 ± 1	0.91 ± 0.21
	H&G	3.5 ± 0.6	4.2 ± 0.5	4.2 ± 1	0.91 ± 0.24

[1] Sensory scale of 1-5 with 5 indicating a fish with good flavor, normal (firm) texture, and no rancidity.
[2] After frozen storage in the laboratory, these fish samples had been frozen for 7 months (3 months in the laboratory plus 4 months aboard the R/V *Miller Freeman*).

Table 5.—Thaw and cooked drip analyses of steak samples cut from whole and H&G Atka mackerel caught in February.

Laboratory storage time[1] (months)	Form	34° thaw (%)	68° thaw (%)	Cooked drip (%)
0	H&G	1.72 ± 0.75	5.49 ± 0.53	20.31 ± 1.44
	Whole	2.60 ± 0.23	6.27 ± 2.45	17.88 ± 1.08
1	H&G	2.97 ± 0.28	5.95 ± 0.66	18.25 ± 0.91
	Whole	3.62 ± 0.22	5.31 ± 0.66	17.07 ± 1.40
2	H&G	2.63 ± 0.77	4.50 ± 0.97	14.98 ± 1.32
	Whole	2.25 ± 0.47	4.43 ± 0.49	13.51 ± 0.58
3	H&G	3.38 ± 0.80	6.23 ± 0.81	
	Whole	3.25 ± 1.26	5.09 ± 0.87	

[1] After frozen storage in the laboratory, these fish samples had been frozen for 7 months (3 months in the laboratory plus 4 months aboard the M/V *Miller Freeman*).

Table 6.—Protein content (%) in the thaw drip from steaks cut from whole and H&G frozen Atka mackerel caught in February.

Laboratory storage time[1] (months)	Form	34° thaw (%)	68° thaw (%)
0	H&G		8.38
	Whole fish		8.53
1	H&G	9.97	8.47
	Whole fish	9.81	8.92
2	H&G	9.60	8.57
	Whole fish	9.42	8.07
3	H&G	7.68	8.26
	Whole fish	7.42	7.69

[1] After frozen storage in the laboratory, these fish samples had been frozen for 7 months (3 months in the laboratory and 4 months aboard the R/V *Miller Freeman*).

Table 7.—Taste panel and drained weight yield evaluations of canned Atka mackerel.

	Sensory examinations					
	Sensory attributes[1]			Overall acceptability (1-9)	Drained weight	
Can treatment[3]	Texture (1-5)	Oiliness (1-5)	Flavor (1-5)		Percent oil	Percent yield
I	3.8±0.5	3.5±0.6	3.5±0.6	6.2±0.5	17.7±1.6	83.0±2.1
II	3.8±0.5	3.8±1	4.0±0	6.5±0.6	3.9±0.5	83.2±2.3
III	3.8±0.5	4.0±1.1	3.5±0.6	6.0±0	4.7±1.1	85.0±1.7
IV	3.8±0.5	3.8±1	4.0±0.8	7.0±0.8	12.8±2.0	81.4±1.4
V	3.8±0.5	3.8±1	3.8±0.5	6.2±0.5	4.3±0.9	81.6±1.3
VI	3.5±0.6	4.0±1.1	3.8±0.5	6.2±0.5	5.4±2.0	82.6±0.4
VII	4.0±0	3.5±1.3	3.8±0.5	6.5±0.6	5.6±0.8	87.5±1.4
VIII	3.8±0.5	3.2±1.2	4.2±0.5	7.0±0	17.1±0.7	89.5±0.8

[1] Scale of 1-5 with 5 indicating a fish with normal (firm) texture, no oiliness, and good flavor.
[2] Hedonic scale of 1-9 with 9 indicating a fish with high acceptability.
[3] Treatment codes and treatments:
I Raw, skin on, ½ teaspoon salt, 1 tablespoon salad oil.
II Raw, skin on, ½ teaspoon salt, 1 tablespoon water.
III Raw, skin on, ½ teaspoon salt, no other additives.
IV Raw, skin off, ½ teaspoon salt, 1 tablespoon salad oil.
V Raw, skin off, ½ teaspoon salt, 1 tablespoon water.
VI Raw, skin on, ½ teaspoon salt, no other additives.
VII Precooked, ½ teaspoon salt, 1 tablespoon water.
VIII Precooked, ½ teaspoon salt, 1 tablespoon salad oil.

from the H&G fish and whole fish were small.

Evaluation of Canned Fish

Taste panelists found that canned Atka mackerel (canned raw, precooked, or smoked) had an acceptable flavor which was further enhanced by the addition of vegetable oil and salt and to lesser degree by the addition of salt and broth. Taste panelists found that canned products had a slight but acceptable oily mouthfeel (Table 7).

The apparent higher drained weight yield for the precooked canned Atka mackerel is explained by the fact that the precooked samples lost most of their cooked drip during the precooked procedure. Thus, when retorted, they appeared to lose less drip than did the canned products prepared from raw fish.

Summary

Although the work reported here is only preliminary, the results indicate that Atka mackerel is a highly edible species of fish that should find a ready acceptance in the U.S. market. Organoleptic evaluations of the fish fillets indicate that the fish is highly desirable. The addition of a slight amount of vegetable oil to the canned products enhanced its acceptability. During the spawning season, Atka mackerel have a higher fat content which imparts a more distinct oily flavor and mouthfeel.

For the same fish length, the fish caught in September were heavier than the fish caught in February. In addition to a higher fat content, Atka mackerel caught in September had significantly higher concentrations of copper, potassium, and sodium than those caught in February. Protein content in the edible portions was not significantly different between the September-caught and the February-caught fish.

Although TBA values, as a measure of rancidity, increased after 3 months of storage at 0°F in the laboratory, Atka mackerel was surprisingly stable and resistant to rancidity as detected by sensory evaluation.

Headed and gutted Atka mackerel yielded about the same amount of cooked drip as the whole fish. Thawing in 68°F water resulted in higher drip losses than thawing at 34°F. Slightly more protein was observed in the drip from the air-thawed fish samples than in the drip from the water-thawed samples.

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