Surimi Preparation from Gulf Menhaden and Its Quality Enhancement

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SURIMI PREPARATION FROM GULF MENHADEN AND ITS QUALITY ENHANCEMENT

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INTRODUCTION

The world catch of small pelagiic species exceeds twenty million tons per annum although half landings are reduced to fish meal. The inherent instability of these materials and the high catch rates achieved require fast, mechanized systems for optimal utilization. Minced technology offers the best potential for increased exploitation. Several of the major negatives of these materials can be overcome by mincing. Fat degradation can be minimized by intimate incorporation of protective additives, proteolytic degradation can be reduced by washing the mince, and protein functionality can be better manipulated in the minced form.

Many mince processes employ a post-separation washing stage. The intention is generally to remove inorganic salts, water soluble proteins, pigments, visceral contamination bacteria and decomposition products. In some species the fat content can also be reduced. Washing of gadoid mince can completely eliminate formaldehyde production from TMAO. Washing is essential in such as kamaboko production where acceptable products cannot otherwise be produced. It is generally achieved by multiple washes in chilled 4°C, preferably chlorinated water, followed by pressing, centrifugation or rotary seiving.

Sixty percent of the world's seafood resources are currently being harvested, therefore, in order to increase seafood production, the existing landings must be used more efficiently.

The coastal herrings are in general small, bony fishes of the family. These include herrings, sardines, anchovies and related species which regularly occur in large schools and contribute more toward world fisheries production than any other species group. The clupeoid fishes have the highest potential yield of any fishery resource in the west-central Atlantic Ocean, Gulf of Mexico and Caribbean Sea areas. The more important species within the group include the Gulf menhaden, Brevoortia patronus, and the Atlantic menhaden, B. tyrannus, which are fully exploited on a harvesting basis but not on the basis of potential economic value. Total production of the two species was 2.5 billion pounds in 1980. Over 99% of total landings were reduced to meal, oil and solubles and the rest was used for ait or canned pet food.

The species is abundant, it is low in cost, and most importantly, the flesh contains functional protein that is necessary to produce a quality surimi product. However, with relatively high proportion of red flesh and a high oil content, menhaden can not be expected to yield surimi as light in color as that prepared from Alaskan pollock.

The purpose of this study was to determine the technical feasibilities of surimi from Gulf menhaden. This purpose can be described in detail:

1. Production of surimi by washing with water only.
2. Production of surimi by washing with sodium bicarbonate-added water and use of centrifuge for dewatering process.
3. Chopping of deboned meat to produce into finer particles of the meat before surimi washing process in order to

investigate if the process facilitates the removal of fat during washing cycle.

4. Compare the surimi produced from different source of fish meat for their functionalities: Surimi prepared with 1) fish fillet, 2) headed and gutted fish, 3) meat recovered from fillet frames.
5. Evaluate the surimi prepared from frozen menhaden.
6. Evaluate the gel-forming abilities of the surimi due to different cooking methods.
7. Evaluate the prepared surimi by Japanese shellfish analog manufacturers and compare with the data generated at the MSU-Seafood Laboratory.
8. Production of nugget type products using menhaden surimi and conduct sensory evaluation for consumer acceptability.

MATERIALS AND METHODS

EXPERIMENT NO. 1

Preparation of Menhaden Surimi Using Pilot Plant Equipment

Surimi was prepared from Gulf menhaden (Brevoortia patronus) within 24 hours held on ice after being caught off the coast of Pascagoula, MS. Fish were deheaded (Model M072, Pisces Industries, Ltd., Wells, MI), eviscerated (Model M017, Pisces Industries, Ltd., Wells, MI), rinsed with water, and run through a deboner (Model NDX13, Bibun Machine Construction Co. Ltd., Japan) with a drum having perforating 5mm in diameter. The minced meat was washed up to seven times with water (10°C), using 1 part fish meat to 4 parts water (w/w). Each washing cycle consisted of 10 minutes of stirring followed by 10 minutes of settling. Each washing cycle of 20 minutes was followed by draining in a rotary rinser. The final rinse was done with water containing 0.3% Nacl to facilitate dewatering.

After the designated number of washings, the slurry was then passed through a refiner (Model RE-120, Bibun Machine Construction Co. Ltd., Japan) to remove undesirable residue such as black skin, bone, and scales. The refined meat was dewatered using a screw press (Model Y5200, Bibun Machine Construction Ltd., Japan). The dewatered meat was chopped in a 50-lb capacity silent cutter (Model VCM 40, Hobart Manufacturing Co., Troy, OH) at a low speed for 30 seconds with sugar, sorbitol, and sodium tripolyphosphate (4%, 4%, and 0.2%, w/w, respectively) and subsequently vacuum-packed in cryobags to be frozen at -40°C in a plate freezer (Model 2735-6A, Dole Refrigerating Co., Lewisburg, TN) and stored at -20°C until used. Determination of Hunter color values and proximate composition were conducted on each surimi.

Preparation of Thermally Induced Surimi Gel

One portion of the thawed surimi preparation of thermally induced surimi gel (2°C, 76.7 - 76.9% moisture) was measured for Hunter color values, L (Whiteness), +a (redness), and +b (yellowness) using the Color Guard System (Model HX-20, Pacific Scientific, Silver Springs, MD). The other portion was chopped with 2.0% salt (w/w, Morton plain salt, Morton Thiokol Inc., Chicago, IL) in a silent cutter for 9 minutes. Ice-chilled water (2°C) was added during chopping to adjust the moisture level to 78%. The resulting paste was stuffed into 30mm diameter cellulose casings and cooked at 90°C for 30 minutes in a water bath. These were immediately cooled in running tap water for 10 minutes. The cooked surimi gels were left at room temperature (22°C) overnight before measuring textural properties, color, and proximate composition.

<u>Instrumental Measurement of Textural Properties</u>

The textural properties of gels measured were compressive force, expressible moisture, and penetration force using an Instron testing machine (Model 1000, Instron Engineering Corporation, Canton, MA). Punch force was measured using a Rheo Tex (Sun Science Co., Ltd., Tokyo, Japan). For all determinations, cylindrical specimens (30mm diameter) were made into 25mm length.

The gel specimen was then placed on a filter paper and compressed at 90% deformation using a 10cm diameter compression head. Failure point during compression was reported as the compressive force. Compressive force was measured as an index of the cohesiveness of the gels.

The moisture collected in the filter paper during compression was converted to percent expressible moisture from each gel specimen.

Penetration force at 90% deformation was measured as an index of firmness using a plunger of 9.5mm in diameter.

Punch force was measured using a Rheo Tex equipped with a plunger of an elipsoidal shape of 5.0mm in diameter. Failure point during penetration of the plunger into a gel specimen and deformation at breakage are multiplied to report as the punch force (gm.cm).

<u>Statistical Analysis</u>

Data were analyzed by the analysis of variance. A least significance test was used to evaluate differences between the means whenever the overall F test was found to be significant.

EXPERIMENT NO. 2

The minced meat was prepared in the same manner as in Experiment No. 1. A total of three washings were conducted for Experiment No. 2. The first washing was performed with water containing 0.5% $NaHCO_3$ (w/w). The second and final washing were carried out with water only and water containing 0.3% Nacl (w/w), respectively.

The slurry was then dewatered using a centrifugal decanter. One portion of the dewatered meat was passed through a refiner and mixed with cryoprotectants, sugar, sorbitol, and sodium tripolyphosphate as described in Experiment No. 1. The other portion was minced with cryoprotectants directly without passing through a refiner. Prepared surimi was frozen and stored at -20°C until used.

Determinations of Hunter color values and proximate composition were conducted.

Preparation of heat-induced surimi gel and measurement of textural properties were performed in the same manner as in Experiment No. 1.

EXPERIMENT NO. 3

One portion of prepared minced meat was further chopped in a 50-lb capacity silent cutter at a low speed for 30 seconds to reduce meat particle size before washing. The other portion was washed without chopping. Washing, preparation of heat-induced surimi gel, and textural properties measurement were conducted in the same manner as described in Experiment No. 2. Hunter color values, proximate composition, and textural properties were determined on surimi and surimi gels.

EXPERIMENT NO. 4

A total of four washings was conducted for Experiment No. 4. Prepared minced meat was washed with 0.5% $NaHCO_3$ solution for the first washing. Second and third washings were carried out with water only. The fourth washing was conducted with 0.3% Nacl solution.

Heat-induced surimi gels were prepared in six different cooking procedures: 1) 90°C for 30 minutes in a water bath, 2) heat-set at 40°C for 30 minutes prior to cooking at 90°C for 30 minutes, 3) chopped surimi paste stuffed in cellulose casings was left at 3°C for 17 hr and cooked at 90°C for 30 minutes, 4) surimi paste stuffed in cellulose casing was left at 3°C for 17 hr was heat-set at 40°C for 30 minutes and cooked at 90°C for 30 minutes, 5) surimi paste in cellulose casing left at 17°C for 17 hr was cooked at 90°C for 30 minutes, 6) surimi paste in cellulose casing left at 17°C for 17 hr was heat-set at 40°C for 30 minutes prior to cooking at 90°C for 30 minutes.

Hunter color values, proximate composition and textural properties were determined.

EXPERIMENT NO. 5

Surimi was prepared in the same manner as in Experiment No. 4 except frozen menhaden was used instead of fresh menhaden. Heat-induced surimi gel was prepared by cooking stuffed surimi paste in a cellulose casing at 90°C for 30 minutes in a water bath. Textural properties were measured as described before.

EXPERIMENT NO. 6

Fresh menhaden was deheaded, eviscerated, rinsed, filleted, and skinned. Prepared fillets were passed through a deboner to obtain mince. Fillet frames were separately passed through a deboner to obtain mince. Two different types of mince (fillet mince, frame mince) were separately processed into surimi in the same manner described in Experiment No. 4.

Fillet and frame surimi gels were separately prepared by four different cooking procedures: 1) 90°C for 30 minutes in a water bath, 2) heat-set at 40°C for 30 minutes, followed by cooking at 90°C for 30 minutes, 3) surimi paste stuffed in cellulose casings were left at 17°C for 17 hr. The paste was then cooked at 90°C for 30 minutes in a water bath, 4) stuffed surimi paste in cellulose casing was left at 17°C for 17 hr. The paste was then heat-set at 40°C for 30 minutes followed by cooking at 90°C for 30 minutes.

EXPERIMENT NO. 7

Menhaden surimi prepared as described in the manner of Experiment No. 4 was distributed to two Japanese, one American and one Korean commercial shellfish analog companies. Data generated at the Mississippi State University-Seafood Research Laboratory and the commercial plants were compared.

EXPERIMENT NO. 8

Menhaden surimi was prepared as described in the manner of Experiment No. 4. Fish nugget type product was prepared at the T. W. Kutter pilot plant using a same ingredient formulation of a nugget product at Daerim America, Inc. Sensory evaluation will follow as soon as the arrangement is made with the Sensory Laboratory of USDA in New Orleans, LA.

RESULTS

EXPERIMENT NO. 1

Table 1 - Effect of washing on Hunter color values

No. of washings	Hunter color values L (Whiteness)	a (redness)	b (yellowness)
1	55.28	2.86	14.95
2	56.25	2.80	13.50
3	57.40	2.78	13.36
4	58.11	2.78	12.95
5	59.23	2.77	12.72
6	59.65	2.65	12.61
7	59.88	2.63	12.49

Table 2 - Effect of washing on proximate composition of washed mince (without cryoprotectants)

No. of washings	Moisture (%)	Ash (%)	Crude protein (%)	Crude fat (%)
1	76.8	0.78	12.77	9.65
2	76.7	0.76	14.21	8.71
3	76.9	0.86	14.25	7.99
4	76.7	0.86	14.89	7.94
5	76.8	0.84	14.60	7.82
6	76.7	0.89	13.98	7.60
7	76.9	0.74	14.01	7.62

Table 3 - Effect of washing on compressive force, expressible moisture, and penetration force.

No. of washings	Compressive force (kg)	% Exp. moisture (%)	Penetration force (g)
1	4.5	7.06	293
2	6.5	0.89	380
3	6.5	0.80	385
4	6.5	0.75	388
5	7.5	0.67	392
6	7.6	0.67	390
7	7.8	0.66	391

Table 4 - Hunter color values of heat-induced surimi gels

No. of washings	Huntercolor values		
	L	a	b
1	65.28	-0.69	9.1
2	67.27	-0.64	8.46
3	68.01	-0.67	8.32
4	68.60	-0.63	8.02
5	69.40	-0.58	7.96
6	69.79	-0.57	7.86
7	69.70	-0.58	7.61

Table 5 - Proximate compositions of heat-induced surimi gels

No. of washings	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	Nitrogen-free extract (%)
1	77.55	2.31	1.52	13.94	4.68
2	77.49	2.25	1.26	13.86	5.50
3	78.55	1.89	1.20	12.77	5.22
4	78.78	1.98	1.24	12.98	5.02
5	77.41	1.87	1.27	13.06	6.39
6	76.44	1.87	1.41	12.75	7.54
7	78.92	1.76	1.35	12.35	5.63

EXPERIMENT NO. 2

Table 6 - Effect of centrifugation followed by refining and centrifugation alone on compressive force, % expressible moisture and penetration force of heat-induced surimi gels

	Compressive force (kg)	Expressible moisture (%)	Penetration force (g)
Centrifugation only	3.44	1.75	402
Centrifugation followed by refining	2.55	2.03	275

EXPERIMENT NO. 3

Table 7 - Effect of chopping of deboned meat into finer particles before washing and compressive force, % expressible moisture, and penetration force of heat-induced surimi gels

	Compressive force (kg)	Expressile moisture (%)	Penetration force (%)
Unchopped	7.58	1.35	1.91
Chopped	7.58	1.31	1.72

Table 8 - Effect of chopping on proximate composition of heat-induced surimi gels

	Moisture (%)	Fat (%)	Ash (%)	Protein (%)	NFE (%)
Unchopped	79.21	4.36	1.30	9.69	5.45
Chopped	79.20	4.34	1.54	10.27	4.65

EXPERIMENT NO. 4

Table 9 - Effect of different cooking on compressive force, % expressible moisture, and penetration force of heat-induced surimi gels

*Types of Gels	Compressive force (kg)	Expressible moisture (%)	Penetration force (g)	Punch force (g.cm)
I	4.4	2.16	6.40	253.08
II	4.23	2.34	6.00	246.27
III	4.60	1.51	7.00	288.26
IV	4.26	1.62	6.70	279.54
V	5.64	1.37	8.60	380.02
VI	5.0	1.71	7.10	333.89

*Type I = Gels cooked at 90°C for 30 minutes

Type II = Gels heat-set at 40°C for 30 minutes followed by cooking at 90°C for 30 minutes

Type III = Gels cooked at 90°C for 30 minutes after placing the stuffed surimi paste in cellulose casings at 3°C for 17 hr

Type IV = Gels prepared by placing the stuffed surimi paste in cellulose casings at 3°C for 17 hr prior to heat-setting at 40°C for 30 minutes and cooking 90°C for 30 minutes

Type V = Gels prepared by placing the stuffed surimi paste in cellulose casings at 17°C for 17 hr, then cooked at 90°C for 30 minutes

Type VI = Gels prepared by placing the stuffed surimi paste in cellulose casings at 17°C for 17 hr prior to heat-setting at 40°C for 30 minutes and cooking at 90°C for 30 minutes

EXPERIMENT NO. 5

Table 10 - Effect of frozen menhaden on compressive force, % expressible moisture, and penetration force

Compressive force (kg)	Expressible moisture (%)	Penetration force (g)
0.95	114	3.63

EXPERIMENT NO. 6

Table 11 - Effect of different source of meat for surimi (fillet and frame) and cooking methods on compressive force, % expressible moisture, penetration force, and punch force

*Types of Gels	Compressive force (kg)	Expressible moisture (%)	Penetration force (g)	Punch force (g.cm)
I	10.84	0.80	640	381.85
II	7.16	1.35	581	310.83
III	14.30	0.72	862	488.28
IV	8.90	1.27	711	420.88
V	5.30	2.50	395	218.74
VI	2.60	2.74	336	142.43
VII	6.63	1.85	404	296.22
VIII	6.10	2.67	309	186.13

* Type I = Gels prepared with fillet surimi cooked at 90°C for 30 minutes

Type II = Gels prepared with fillet surimi, heat-set at 40°C for 30 minutes, cooked at 90°C for 30 minutes

Type III = Gels prepared with fillet surimi, cooked at 90°C for 30 minutes after stored at 17°C for 17 hr

Type IV = Gels prepared with fillet surimi, heat-set at 40°C for 30 minutes after being stored at 17°C for 17 hr, then cooked at 90°C for 30 minutes

Type V = Gels prepared with frame surimi, cooked in the same manner as Type I

Type VI = Gels prepared with frame surimi, cooked in the same manner as Type II

Type VII = Gels prepared with frame surimi, cooked in the same manner as Type III

Type VIII= Gels prepared with frame surimi, cooked in the same manner as Type IV

Table 12 - Effect of different source of mince on proximate composition of surimi and surimi gels

Source of mince	Sample	Moisture (%)	Ash (%)	Crude Protein (%)	Crude Fat (%)	NFE (%)
Fillet	surimi	76.6	1.0	14.8	0.3	7.3
	gel	73.9	2.5	18.7	0.2	5.1
Frame	surimi	76.8	1.1	14.6	0.11	6.7
	gel	73.8	2.4	17.5	0.2	6.1

Table 13 - Hunter color values of surimi prepared with fillet mince and frame mince

Source of mince for surimi	L(whiteness)	a(redness)	b(yellowness)
Fillet	61.16	2.52	12.42
Frame	69.35	0.59	10.55

EXPERIMENT NO. 7

Table 14 - Data generated by Top Trans Ocean Products (a subsidiary of Taiyo Fisheries of Japan) on menhaden surimi

Material Name	Date	Moisture (%)	pH	Defects
Menhaden	May 6, 1993	73.4	7.22	41/10 gm

Table 15 - Data generated by Top Trans Ocean Products (a subsidiary of Taiyo Fisheries of Japan) on menhaden surimi gel

Sample Name	Immediate[1]			Suwari[2] (30°C for 60 min)			Suwari[3] (5°C for 22hr)		
	JS[4]	DB[5]	Color[6]	JS	DB	Color	JS	DB	Color
Menhaden	267	6.2	71.2	279	6.4	71.0	314	6.6	71.0

1 = Cooking at 90°C for 40 minutes

2 = Heat-set at 30°C for 60 minutes, followed by cooking at 90°C for 40 minutes

3 = Cold-set at 5°C for 22 hr, followed by cooking at 90°C for 40 minutes

4 = Jelly strength in gm using a Rheo-Tex

5 = Deformation at breakage in mm using a Rheo-Tex

6 = Hunter color value of whiteness

Table 16 - Data generated by Unisea Foods, Inc. (a subsidiary of Nippon Suisan of Japan) on menhaden surimi

Material	Moisture (%)	pH	Hunter color values L	Hunter color values a	Hunter color values b	Impurities (per 10gm surimi)
Menhaden	74.34	7.14	58.93	2.50	12.6	3

Table 17 - Data generated by Unisea Sea Foods, Inc. (a subsidiary of Nippon Suisan of Japan) on menhaden surimi gel

Name	Control[1]				
	JS[3]	DB[4]	Hunter color values L	a	b
Menhaden	259	7.61	69.42	0.12	14.37
	Suwari[2]				
	JS	DB	Hunter color values L	a	b
Menhaden	273.6	7.2	69.98	0.03	14.44

1 = Cooked at 90°C for 40 minutes

2 = Heat-set at 40°C for 30 minutes and cooked at 90°C for 40 minutes

3 = Jelly strength in gm using a Rheo-Tex

4 = Deformation at breakage in mm using a Rheo-Tex

Table 18 - Data generated by Seafest of Prepared Food Division of Multifoods on menhaden surimi

Date	Compositional Properties (Raw) Moisture (%)	Protein (%)	pH	Impurities	Odor
May 12, 1993	70.90	16.16	7.43	1.0	2

Table 19 - Data generated by Seafest of Prepared Food Division of Multifoods on menhaden surimi gel

Name	Torsion Test[1] Shear stress (kpa)	Torsion Test[1] True shear strain	Punch Test[2] Force	Punch Test[2] DB	Hunter color values L	a	b
Menhaden surimi gel	12.10	1.4	66	0.3	72.82	-1.36	13..95

1 = Brookfield viscometer was used to twist the gel until the gel breaks

2 = Rheo-Tex was used to obtain force in gm and deformation at breakage in cm

EXPERIMENT NO. 8

Fish nugget type products were made at the pilot plant of T. W. Kutter, Inc.

Meat portion of the nugget product was formulated by blending and increasing amount of menhaden surimi up to 50% with decreasing amount of whiting mince. The rest of the ingredient formation was identical with the ingredient formulation of the product of Daerim America, Inc.

Sensory evaluation is yet to be done at USDA Agricultural Research Service in New Orleans, LA. An arrangement for the project is being made.

EXPERIMENT NO. 9

Menhaden mince was prepared in the same manner as described in Experiment No. 1 and stored in the walk-in freezer at (-30°C) until it is shipped overnight packed in dry ice to Mississippi State University Food Processing Laboratory, Starkville, MS. The boxes were then stored in a walk-in freezer (-17°C) upon arrival at the campus.

The mechanically deboned fish muscle (MDFM) was thawed at 4°C for 48 hr before use.

Phosphate buffers of pH 5.0 ± 0.2, 6.0 ± 0.2, 7.0 ± 0.2, 8.0 ± 0.2, 9.0 ± 0.2, and 10.0 ± 0.2 were prepared with analytical grade $NaH_2PO_4.H_2O$ and Na_2HPO_4 (Fisher Scientific, Fair Lawn, NJ) by the procedures of Gomori (1955). Chilled distilled water was used to make the different buffer solutions which were then stored at 4°C until use.

There were 6 pH treatments and a control (no buffered solution but only potable water (pH= XX) was used for the latter). The washing process called for a batch ash system: 1st cycle (4 parts of water to 1 part of mince): One kilogram of MDFM was washed with four liters of phosphate buffer at pH 5.0 ± 0.2, 610 ± 0.2, 7.0 ± 0.2, 8.0 ± 0.2, 9.0 ± 0.2, 10.0 ± 0.2 and potable water (control) at 4°C. The mixture was manually stirred for 3 minutes and after 15 minutes of settling time was filtered through a double layer of fine cheese cloth and the water pressed out by hand. As much as possible of floating particles of fat were removed. Second and third cycles (5 parts of water to 1 part of mince): The fish paste from the first cycle was washed with 5 liters of potable water at 4°C. In the third cycle, 0.15% (w/w) of NaCl (commercial salt) was used. After each cycle, the mixture was hand stirred for 3 minutes and after 5 minutes, the rest was filtered through a double layer of fine cheese cloth. The fish paste was further pressed using a Model YS200 Screw Dehydrator (Bibun Machine Construction Co., Ltd., Japan) to reduce the moisture content. Washed meat was weighed to separate samples used for different chemical analyses from the one used for the preparation of the gels.

Table 20 - Mean carbonyl and TBA values of menhaden mince as affected by different washing treatments

Treatments	Carbonyls (10^{-7} mole/g)	* TBA
pH 5	3.20 ab	4.53 a
pH 6	2.70 bc	6.73 ab
pH 7	1.70 bc	5.90 a
pH 8	1.57 c	5.00 a
pH 9	2.03 bc	4.77 a
pH 10	1.50 c	6.37 ab
Tap Water	2.33 bc	6.67 ab
Unwashed	4.63 a	8.40 b
Overall mean	2.46	6.05
CV (%)	36.01	22.59
SEM	0.78	1.87
LSD (0.05)	1.55	2.39

abc - Means within columns not followed by a common letter differences (P 0.05).

CV - Coefficient of variability

SEM - Standard error of the mean

LSD - Lease significant differences at 5% level of probability

* mg malonaldehyde/kg mince

Table 21 - Mean carotenoids and hematin values of menhaden mince as affected by different washing treatments

Treatments	Carotenoids (dry basis) (ppm)	Hematin (dry basis) (ppm)
pH 5	1.07 a	0.27 bc
pH 6	0.70 a	0.17 c
pH 7	0.87 a	0.23 bc
pH 8	0.90 a	0.17 c
pH 9	0.90 a	0.67 ab
pH 10	1.03 a	0.63 abc
Tap Water	0.57 a	0.27 bc
Unwashed	0.63 a	1.07 a
Overall mean	0.83	0.43
CV (%)	45.24	64.17
SEM	0.14	0.08
LSD (0.05)	0.66	0.49

abc - Means within columns not followed by a common letter differ (P 0.05).

CV - Coefficient of variability

SEM - Standard error of the mean

LSD - Least significant differences at 5% level of probability

Table 22 - Mean moisture values of menhaden gel and mince as affected by different washing treatments

Treatments	Mince Moisture (%)	Gel Moisture (%)
pH 5	81.30 b	77.90 a
pH 6	81.63 b	78.30 a
pH 7	84.77 ab	79.20 a
pH 8	85.47 a	79.23 a
pH 9	86.60 a	79.77 a
pH 10	86.30 a	78.67 a
Tap Water	78.63 b	77.13 a
Unwashed	71.87 c	N/A
Overall mean	82.07	78.54
CV (%)	2.24	1.14
SEM	3.37	0.80
LSD (0.05)	3.22	1.57

abc - Means within columns not followed by a common letter differ (P 0.05).

N/A - Data not available

CV - Coefficient of variability

SEM - Standard error of the mean

LSD - Least significant differences at 5% level of probability

Table 23 - Mean Hunter color and values of menhaden mince as affected by different washing treatments

Treatments	L	a	b
pH 5	51.92 a	0.11 bc	10.37 a
pH 6	51.70 a	0.33 bc	10.44 a
pH 7	51.44 a	0.16 bc	9.97 a
pH 8	52.98 a	0.28 bc	9.64 a
pH 9	53.27 a	-0.06 c	10.08 a
pH 10	51.95 a	0.13 bc	9.90 a
Tap Water	51.28 a	0.72 b	10.65 a
Unwashed	41.41 b	4.49 a	11.18 a
Overall mean	50.74	0.77	10.28
CV (%)	3.18	56.27	5.48
SEM	2.60	0.19	0.32
LSD (0.05)	2.82	0.76	0.99

abc - Means within columns not followed by a common letter differ ($P < 0.05$).

CV - Coefficient of variability

SEM - Standard error of the mean

LSD - Least significant differences at 5% level of probability