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Color, Cooking Loss and Textural Properties of Patties as Affected by Catfish Belly Flap Mince Size and Cooking Method

Jin M. Kim
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ABSTRACT. Patties were prepared with different sizes of channel catfish belly flap mince. Belly flap meat was minced using four different sizes of openings of plate, mixed with salt, formed, and cooked by two methods, in water and oven. Results indicated no differences ($p > 0.05$) in Kramer shear break force in the patties cooked by different methods for the same size of mince. As the size of meat particles for patties decreased, hardness and gumminess increased, and color differed from fillet, but Kramer shear break force as well as percent cooking loss decreased ($p < 0.05$). Patties cooked in an oven showed greater color difference from fillet, percent cooking loss, hardness, and gumminess than those cooked in water for the same size of meat particles ($p < 0.05$). doi:10.1300/J030v16n01_03 [Article copies available for a fee from The Haworth Document Delivery Service: 1-800-HAWORTH. E-mail address: <docdelivery@haworthpress.com> Website: <<http://www.HaworthPress.com>>.]

KEYWORDS. Patties, catfish belly flap, mince size, cooking methods, cooking loss, color, texture

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INTRODUCTION

Channel catfish (*Ictalurus punctatus*) is the leading aquaculture product in the US, and consumption of catfish has increased dramatically over the past decade. Processed weight increased from 381 million to 597 million pounds between 1991 and 2001, and fresh and frozen sales increased from \$417 million to \$658 million during the same period (USDA/NASS, 2002). Per-capita consumption of catfish increased from 0.41 pounds in 1985 to 1.15 pounds in 2001, an increase of 180% (NFI, 2002; Mississippi State University Extension Service, 2002).

As the catfish industry developed, increasing amounts of catfish have been filleted into further-processed, higher value products for marketing. The yield of catfish when processed as whole fillets, is ~40% (fillet: 32%, belly flap: 7%) generating about 60% by-product (head: 15%, viscera: 22%, frames: 20%, skin: 3%) (Redger, 2004), while that of cod orred hake is ~34%, generating about 66% by-product (head: 16%, viscera: 26%, frames: 24%) (Lee, 2004). Consequently, interest is high among processors and researchers in developing higher value products from this by-product, particularly the flesh remaining on the "frames" after filleting (Lee, 1989; Kim et al., 1996). Catfish fillet frames were used to produce surimi (Kim et al., 1996), and catfish surimi was compared with commercial Alaska pollock surimi for their heat-induced gel-forming behavior (Kim et al., 1992).

A recent survey on farm-raised channel catfish consumption in the US indicates the various reasons for which it is not consumed—taste, texture, smell, and lack of preparation knowledge (House et al., 2003). Flavor was not only the most important reason why consumers ate catfish, but it also was the primary reason why non-consumers did not eat catfish. These authors concluded that changing non-consumer perceptions of taste, smell, and texture properties of catfish likely would be difficult. Therefore, developing value-added products that appeal to a broader range of consumers is necessary in order to increase demand for channel catfish in the US.

Fat, moisture, protein, and ash content vary within sections of the fillet of fish (Morkore et al., 2002). During processing, the channel catfish fillet is trimmed to remove the abdominal meat; these trimmings are called belly flap meat. Compared with fillet meat, channel catfish belly flap meat has a high fat content, which limits shelf life and detracts from sensory qualities. Post-harvest handling and processing methods to reduce the channel catfish belly flap meat fat content will enhance the quality, functionality, and sensory characteristics of its value-added

products. Adding value to belly flap meat, a low-value product relative to fillets, will increase product utilization and profitability of processing, and possibly increase consumer appeal for channel catfish products.

The mechanism of heat-induced binding of meat particles has been studied extensively under various processing conditions (Vadehra and Baker, 1970; Acton et al., 1983; MacFarlane et al., 1977; Xiong, 1993; Xiong and Blanchard, 1994; McCord et al., 1998). However, only limited published information exists on the binding properties of a series of different sizes of meat particles and its effect on finished product properties. This is particularly true for restructured fish products, where most research has focused on mechanisms of heat-induced binding and gel forming behavior of muscle proteins, myosin, actin, actomyosin, and myosin-subunits (Samejima et al., 1969; Lee and Toledo, 1976; 1979; Niwa et al., 1980; Lee, 1984; Makinodan et al., 1984; Iso et al., 1986; Schwartz and Lee, 1988; Chan et al., 1992; Youngsawatdigul and Park, 1999). Therefore, the objectives of this study were to (1) investigate the feasibility of developing a patty using channel catfish belly flap meat and (2) optimize patty preparation by evaluating the effects of catfish belly flap mince particle size and cooking methods on patty properties.

MATERIALS AND METHODS

Proximate Analysis

Channel catfish fillet and belly flap meat samples were subjected to proximate analysis. All samples were dried prior to analysis at 105°C for 16 h in a gravity convection oven (Fisher Isotemp, Fisher Scientific, Pittsburgh, PA) and were cooled in a desiccator. Moisture, crude protein, fat, ash, and carbohydrate were determined using standard procedures (AOAC, 1990).

Patty Preparation

A 6.8 kg box of fresh belly flap meat was purchased within 6 h of production on each of 8 different dates from a commercial catfish processor. Upon receipt, the belly flap meat was divided into four lots and was minced (Model 722, Biro Manufacturing Co. Ltd., Marblehead, OH) through one of four different types of plates. The size and number of openings on each 82-mm diameter plate and resultant mince

were designated S1: three kidney-shaped openings each measuring approximately 18×35 mm (6.20 cm^2); S2: six 18-mm diameter circular openings; S3: 24 9-mm diameter circular openings; and S4: 102 4.5-mm diameter circular openings. Mince was combined immediately with 2% salt (w/w), mixed (Model KSM150PSOB, KitchenAid, St. Joseph, MI) for 5 min at low speed (80 rpm), and formed into a patty (3.5 cm thickness, 8 cm diameter) using a hamburger press (Model 1404, Univex, Salem, NH). Each patty was weighed to 220 g. On each date, 2-5 patties within mince size were assigned randomly to cooking method and textural measurement.

Patties either were cooked in a water bath (W) at 95°C , or baked (B) in a convection oven (Model OV-350, UNO, Vigodarzere, Italy) at 176°C . All patties were cooked to an internal temperature of 80°C . A thermocouple (Model 701, Jenco Electronics, Ltd., San Diego, CA) was inserted into the geometric center of patty to determine the required cooking time for each cooking method. Prior to cooking in the water bath, patties were packed individually in a boil-in-bag and sealed with mild vacuum. Following cooking in the water bath, patties were cooled immediately in running tap water for 20 min. Oven-baked patties were placed immediately in plastic bags and cooled as the boiled patties. Cooled patties were left to equilibrate to room temperature (22°C) for 24 h before further analyses.

Cooking Loss

Following equilibration to room temperature, fluid lost during cooking in the boil-in-bag was drained. Both sides of the patties were then lightly patted with the double layers of paper towel, and patties were weighed. Baked patties were weighed directly. The percent cooking loss was calculated as follows: $\text{Cooking loss (\%)} = [(P_i - P_f)/P_i] \times 100$, where P_i = patty initial weight (g) and P_f = patty final weight (g).

Color Measurement

Commission Internationale de l'Eclairage L^* (whiteness), a^* (redness-greenness), and b^* (yellowness-blueness) values of cooked catfish patties were measured using an X-Rite Spectrophotometer (Model SP 62, X-Rite, Grandville, MI). The spectrophotometer was calibrated with an aperture of 4 mm diameter. Color measurement was carried out directly on the patties. Quadruplicate measurements were performed for each

experimental treatment. Total color difference (ΔE) of cooked catfish patties as compared with a catfish fillet or unprocessed belly flap meat was calculated using the following equation (Woyewoda et al., 1986): $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$. The catfish fillet and unprocessed belly flap meat were cooked in a water bath following the same procedure used for the patties.

Textural Properties

Shear break force was measured using a Kramer shear cell (internal dimensions of $6.6 \times 7.3 \times 6.4$ cm, $L \times W \times H$) connected to an Instron testing machine (Model 3342, Instron Corporation, Canton, MA). Each cooked patty sample was adjusted to a 6.5-cm diameter and 3.0-cm height for analysis. The Kramer shear cell was equipped with a single, blunt-end blade (3 mm thick) that descended at 5 mm/min (Wardlaw et al., 1973; Wheeler et al., 1994, 1996, 1997; Shackelford et al., 1999a, b; Bourne, 2002; Shackelford et al., 2004a, b). Failure point during cutting-shear was reported as Kramer shear break force in Newton.

A compression test was performed using a 10-cm diameter plunger attached to an Instron testing machine (Model 3342, Instron Corporation, Canton, MA). Cooked patties were adjusted to 7.5 cm diameter and 3.0 cm height using a circular cutter prepared at a local machine shop and a meat slicer (Model DSL-9, Dito Dean Food Prep, Rocklin, CA). As each patty specimen was compressed to 15% deformation, the plunger was withdrawn to the original height, the sample was rested for 5 s, and the sample was subjected to a second compression-withdrawal cycle to 15% deformation. Speed of compression head was adjusted to 5 mm/min.

The hardness value is the peak force of the first compression (Bourne, 2002). Springiness is how well a product physically springs back after it has been deformed during the first deformation and the percentage of second peak force divided by peak of first peak force (Bourne, 2002). Resilience is a measurement of how a sample recovers from deformation in relation to speed and force derived (Szczeniak, 1963) and is measured as the percentage of the area under the decompression portion divided by the area under the compression portion in the first curve (Bourne, 1978). Cohesiveness is how well the product withstands a second deformation relative to how it behaved under the first deformation (Bourne, 2002), and is measured as the percentage of the area under the compression portion of the second curve divided by the area under the compression portion of the first curve (Bourne, 1966, 1975,

1976). Gumminess is defined as the product of multiplying hardness and cohesiveness.

Statistical Analysis

This experiment utilized a split plot design with blocking, where purchase date was the block effect, mince size was the whole-plot factor, and cooking method was the split-plot factor. Data were analyzed using Proc Mixed, a SAS 9.1.3 procedure (SAS Institute, Cary, NC, USA; Littell et al., 1996), where date was treated as a random block effect, and mince size and cooking method were treated as fixed effects. Least squares means were calculated for fixed effects and differences among means were declared significant at $\alpha = 0.05$.

RESULTS AND DISCUSSION

The protein content of fillet (CCF) and unprocessed belly flap meat (CCBFM) did not differ (Table 1). However, fat content was greater and moisture content was lower in belly flap meat compared with fillet meat. Wiles et al. (2004) reported channel catfish belly meat protein, fat, and moisture contents of 16.9%, 11.2%, and 72.6%, respectively.

Color differed significantly ($p < 0.05$) between CCF and patties prepared with CCBFM mince (Table 2). Fillet meat had the highest whiteness (L^*). The darker colors of patties prepared with CCBFM were attributed to dispersion of smeared black peritoneal membrane of belly flap that happened during mincing and mixing with salt. As the size of mince decreased, color difference increased because of a more homogeneous distribution of more finely comminuted black peritoneal membrane particles. Baked patties had greater color difference compared with fillets than patties cooked in water. Slight burning on the surface of

TABLE 1. Proximate analyses (%) of channel catfish belly flap and fillet meat.

Sample	Protein	Lipid	Carbohydrate	Ash	Moisture
Belly flap meat	15.2 ^a	11.4 ^b	0.15 ^a	0.85 ^a	72.4 ^a
Fillet	16.1 ^a	6.6 ^a	0.18 ^a	0.82 ^a	76.3 ^b

Values are means of three analyses.

^{ab}Means within column followed by different letters are significantly different ($p < 0.05$).

TABLE 2. Color CIE for channel catfish fillet and belly flap meat, and for patties prepared with different size of belly flap meat mince (S1-S4, see text for details) and cooked in a water bath (W) or oven (B).

Treatment	L^*	a^*	b^*	Color Difference (ΔE) ¹
Fillet	84.2	-0.86	12.24	
Belly Flap Meat	39.1	0.85	4.52	45.84
S1W	68.3 ^c	-1.03 ^{ab}	10.55 ^a	16.00 ^b
S2W	71.7 ^d	-1.81 ^b	10.62 ^a	12.74 ^a
S3W	71.7 ^d	-1.23 ^{ab}	11.08 ^a	12.58 ^a
S4W	69.3 ^{cd}	-1.20 ^{ab}	10.63 ^a	15.09 ^{ab}
S1B	68.5 ^{bcd}	-1.06 ^{bc}	15.42 ^{ab}	16.77 ^b
S2B	65.0 ^{ab}	-0.59 ^{ac}	18.39 ^{bc}	20.46 ^c
S3B	64.3 ^a	-0.60 ^{ac}	18.86 ^{bc}	21.02 ^c
S4B	64.0 ^a	-0.93 ^{ab}	15.32 ^{ac}	20.70 ^c

Values are means of four observations per duplication.

¹ $\Delta E = [(\Delta L)^2 + (\Delta a)^2 + (\Delta b)^2]^{1/2}$; compared to fillet.

^{abcd}Means within column for patty treatments only followed by different letters are significantly different ($p < 0.05$).

patties during baking may have caused increased values in b^* and a^* as well as decreased value in L^* , resulting in increased color difference in baked patties.

Cooking loss (%) decreased significantly for both cooking methods as mince particle size decreased (Figure 1). This is because particle surface area increases as particle size decreases. Consequently, more myofibrillar proteins are solubilized when finely minced meat is mixed with salt compared with coarsely minced meat. The solubilized myofibrillar proteins bind minced catfish when heat is applied.

In this study, the S4 mince became viscous when mixed with salt because the increased particle surface area resulted in solubilization of a larger amount of myofibrillar proteins. Mechanical beating of S1 particles with salt promotes solubilization of myofibrillar proteins mostly on the surface of the particles. When these CCBFM particles were formed into a patty and cooked, solubilized myofibrillar proteins on the surface of the particles functioned as a binder, but proteins located inside the meat particles remained intact. S1 patty tended to lose more moisture than S4 patty upon cooking. Therefore, it is clear that salt-solubilized myofibrillar proteins hold more moisture than intact myofibrillar proteins when they are subjected to heat-induced gelation.

FIGURE 1. Cooking loss of patties due to different sizes of meat particles and cooking methods. Belly flap meat was minced through plates with openings of 0.16, 0.64, 2.54, or 6.20 cm².

Salt-solubilized myofibrillar proteins on the surface of large mince particles (S1) and whole mince in the case of small mince size (S4) first formed a loose protein network, known as a "suwari" gel between actomyosin and myosin molecules as patty temperature increases from 30° to 50°C (Shimizu et al., 1981; Suzuki, 1981). Actomyosin hydrates and forms a network of hydrogen bonds during "suwari" gelation. Allowing heat-denatured muscle proteins to align and aggregate before further heating, appeared to strengthen the interactions formed during suwari setting (Douglas-Schwarz and Lee, 1988; Roussel and Cheftel, 1988). Additionally, formation of large aggregates through cross-linking of myosin heavy chains is required to form an elastic gel (Niwa et al., 1989; Numakura et al., 1989; Yamashita et al., 1989; Lee et al., 1990; Chan et al., 1992). When patty temperature increases to 50°-70°C, part of gel structure is disrupted; this phenomenon is known as "modori." At temperatures above 70°C, an elastic protein gel forms as fibrous myofibrillar protein molecules form a network structure, which increases gel strength

(Sano et al., 1990a, b). Hydrogen bonding, hydrophobic bonding (Suzuki, 1981), and S-S bonding (Stone and Stanley, 1992) contributes to increased gel strength. Water is retained in hydrogen and hydrophobic bonds between actomyosin molecules and in the random coils of these molecules that form during heating. As the amount of actomyosin subjected to the gelation process increases, more water becomes trapped in the protein linkages, which results in decreased moisture loss upon cooking.

The Kramer break force decreased significantly within cooking method as the mince particle size decreased (Table 3). However, the Kramer break force within a given mince particle size was unaffected by cooking method. The linkages among protein molecules that occur during gelation of solubilized myofibrillar proteins of finely minced catfish muscle, while strong and elastic, likely lack the structural integrity and resistance to cutting of coarsely minced catfish muscle by a blade in Kramer shear cell.

Contrary to the Kramer break force, the rheological parameters hardness and gumminess increased within cooking method as mince particle size decreased (Table 4). As mentioned earlier, more myofibrillar proteins were extracted when smaller meat particles were mixed with salt because of the increased surface area exposed to salt. Therefore, data in Table 4 indicate that salt-extracted myofibrillar proteins demonstrated higher rheological parameters than intact myofibrillar proteins when denaturation occurs by heat. It has been claimed that cooking yield and binding strength are directly proportional to meat particle surface area in beef rolls (Pepper and Schmidt, 1975; Moore et al., 1976) and chicken loaves (Acton, 1972). Results of the present study on cooking loss (Figure 1) and binding strength (Table 4) are consistent with the earlier studies. Patties cooked in an oven had significantly higher hardness and gumminess compared with those cooked in water (Table 4). This was

TABLE 3. Kramer shear break force (N) for patties prepared with four particle sizes of channel catfish belly flap mince (S1-S4, see text for details) and cooked in a water bath or oven.

Cooking Method	Mince Size			
	S1	S2	S3	S4
Water Bath	37.9 ± 2.06 ^a	35.9 ± 1.98 ^b	33.8 ± 1.84 ^c	27.6 ± 1.96 ^d
Oven	38.2 ± 2.09 ^a	34.6 ± 1.97 ^b	33.7 ± 1.99 ^c	27.1 ± 1.99 ^d

Values are means of four observations per duplication.

abcd Means for patty treatments only followed by different letters are significantly different ($p < 0.05$).

TABLE 4. Texture profile analysis for patties prepared with one of four particle sizes of channel catfish belly flap mince (S1-S4, see text for details) and cooked in a water bath or oven. Each patty was subjected to two compression cycles to 15% deformation, with a 5-s rest between cycles.

	Hardness	Springiness	Resilience	Cohesiveness	Gumminess
Treatment	(N)	(%)	(%)	(%)	(N)
S1W	21.0 ± 0.95 ^a	96.4 ± 0.37 ^a	49.4 ± 1.00 ^a	78.3 ± 0.91 ^a	16.4 ± 0.76 ^a
S2W	22.0 ± 0.94 ^b	95.7 ± 0.37 ^b	48.7 ± 0.97 ^b	77.4 ± 0.89 ^b	17.1 ± 0.76 ^b
S3W	25.2 ± 0.79 ^{bc}	95.6 ± 0.32 ^b	47.7 ± 0.87 ^c	76.7 ± 0.77 ^c	19.3 ± 0.64 ^c
S4W	27.1 ± 0.98 ^d	96.2 ± 0.39 ^a	47.2 ± 1.05 ^c	76.9 ± 0.95 ^c	20.9 ± 0.79 ^d
S1B	23.2 ± 1.09 ^{ab}	96.0 ± 0.42 ^a	48.4 ± 1.10 ^b	78.6 ± 1.00 ^a	18.2 ± 0.87 ^{ab}
S2B	25.4 ± 1.04 ^{bc}	95.2 ± 0.40 ^b	49.0 ± 1.05 ^a	78.1 ± 0.96 ^a	19.8 ± 0.83 ^c
S3B	29.7 ± 1.00 ^{cd}	95.4 ± 0.38 ^b	48.9 ± 0.97 ^b	77.8 ± 0.90 ^b	23.1 ± 0.80 ^{bc}
S4B	31.6 ± 1.04 ^{bd}	96.1 ± 0.40 ^a	48.0 ± 1.05 ^b	78.4 ± 0.97 ^a	24.8 ± 0.83 ^{bd}

Values are means of four observations per duplication.

^{abcd}Means within column for patty treatments only followed by different letters are significantly different ($p < 0.05$).

attributed to a greater loss of water in oven-cooked patties (Figure 1), resulting in further hardening of the patties compared with those cooked in water. However, there was no significant change in patty springiness, cohesiveness, and resilience due to meat particle size or cooking method.

The rheological parameters of meat are drastically changed during heat processing of meat. This is mainly attributed to the thermal denaturation of proteins in the meat, though there are interactions between proteins, lipids, and hydrocarbonate (Iso et al., 1984). Most studies on the rheological properties of fish meat materials are usually limited to those of kamaboko or surimi gel. Unlike surimi and small catfish meat particles in this study (S3 or S4), portions of myofibrillar proteins in large meat particles, which are located inside meat particles (S1 or S2), have not been solubilized during mixing with salt. When denatured, it did not exert resistance upon compression as much as salt-solubilized proteins did (Table 4).

Kauzman (1959) defined protein denaturation as "a process in which the spatial arrangement of the polypeptide chains within the molecule is changed from that typical of the native protein to a more disordered arrangement." This change generally can be represented as a transition

from a native (folded) to a denatured (unfolded, disordered state) structure. In the case of carp meat (Iso et al., 1984), rheological parameters decreased sharply until 50°C, and then they gradually increased. The sharp decrease of the rheological parameters until 50°C was attributed mainly to the breaking of intermolecular and intramolecular hydrophobic and hydrogen bonds as a result of thermal denaturation of proteins or by breaking the protein chain by protease. It has been well documented that there are species variations in muscle proteinase activity among fish species (Hashimoto et al., 1982; Iwata et al., 1974; Makinodan et al., 1984).

In fish muscle there exist various proteases. Known ones are cathepsin D (Makinodan, 1982), Ca^{++} -nondependent neutral proteinase (Makinodan, 1984), cathepsin B (Makinodan, 1982), and alkaline proteinase (Iwata et al., 1974). Both the neutral and the alkaline proteinases are unique enzymes that were found originally in fish muscle, and alkaline proteinase is known to be heat stable. There has been no report on muscle proteinase activities in catfish meat. Carp muscle proteins completely attained the change of the structure at 50°C, but the thermal denaturation of proteins continues until 70°C. The gradual increase of the rheological parameters after 50°C may be attributed to hardening of the carp meat by water loss (Iso et al., 1986). A similar phenomenon was found in pork (Tuomy and Lechner, 1964). Catfish patty in this study was cooked until internal temperature reached 80°C resulting in water loss and hardening of patties may have been a little exaggerated. Therefore, differences in water loss and rheological parameters among patties prepared with different sizes of mince particles may have been more distinctive.

CONCLUSIONS

Differences occurred in color, percent cooking loss, and textural properties, such as Kramer break force, hardness, and gumminess among patties prepared with different sizes of catfish belly flap mince. Results of Kramer shear break force test using a blade indicate higher failure point on patties prepared with larger mince particles. The linkages among protein molecules that occur during gelation of solubilized myofibrillar proteins of finely minced catfish muscle, although strong and elastic, lack the structural integrity and resistance to cutting of coarsely minced catfish muscle by a blade in Kramer shear cell. On the other hand, compression test revealed lower hardness and gumminess for patties prepared with larger mince particles. Data indicate that channel catfish

belly flap meat has functional properties with potential use for commercial production of fabricated products. Finally, as demand for utilization of by-product generated during filleting grows, other by-products, such as meat recovered from fillet frames, should be investigated further as sources for value-added product development.

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