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Effects of Washing on the Functional Properties of Duck Meat

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Abstract: The objective of this research was to study the effect of washing cycles on the functional properties of washed duck meat. Five types of treatment were applied in this study: unwashing, single, double, triple and quadruple washing. The washing cycles were found to reduce fat content and protein content significantly. The quadruple washing resulted in the lowest cholesterol and myoglobin contents. Double washing showed significantly higher Lightness (L^*) and Whiteness (W) values than the other washing cycles. Washing cycles increased the shear force of the samples ($p > 0.05$). Washing cycles also significantly affected pH, folding test, gel strength, expressible moisture and WHC; quadruple washing exhibited a significantly higher pH, folding score, expressible moisture and WHC but reduced the gel strength of the sample. Sample treated with a double washing cycle exhibited the highest folding score, a low fat content and the best lightness and whiteness values.

Key words: Duck meat, surimi like material, functional properties, washing treatment, cholesterol

INTRODUCTION

Duck meat is a less valued poultry meat and rare to be developed into food products due to the some consumers' perception towards it's contain higher fat and possess strong ducky like flavor. By introducing surimi technology into processing of duck meat may evolve its popularity and consumptions. In this study, the surimi technology involves was washing cycle. The main functions of washing were to remove fat, blood, enzyme, sarcoplasmic proteins and perhaps could reduce as much as possible ducky like flavor or odor of duck meat. Washing treatments was known, was the successful method in stabilize fish surimi for past several years. Therefore, by applying surimi technology in the production of value product from duck meat (e.g. surimi-like material) in the future could provide a new approach towards increasing its value and utilization.

Few studies have been performed on the processing and utilization of duck meat. Duck meat is an unpopular poultry meat compared to chicken because of its less acceptable qualities in terms of its distinctive flavor, cooking odor and darker color. Additionally, meat from spent ducks is sold at a very low retail price.

Surimi is a Japanese term, which defines a concentrate of myofibrillar proteins obtained after mincing and water washing of fish flesh (Park and Morrissey, 2000). Surimi is light in color, has a bland odor, low in fat and high in myofibrillar protein and extremely functional due to the unique gelling properties of these myofibrillar proteins and these qualities make surimi an ideal functional ingredient for fabricating new food products (Lanier, 2000).

Previous research has indicated that the washing techniques available for surimi processing can also be applied to improve the functional properties of duck meat. The washing solutions used in those techniques have included tap water (Benjakul *et al.*, 2003; Ensoy *et al.*, 2004); 0.04M sodium phosphate buffer solution and 0.5% sodium bicarbonate solution (Ensoy *et al.*, 2004) and 0.1 M sodium chloride solution (Baxter and Skonberg, 2008; Ensoy *et al.*, 2004).

Yang and Froning (1990) reported that tap water, phosphate buffer solution, sodium bicarbonate solution and sodium chloride solution were effective for the removal of heme pigments. Alkaline washing conditions removed the heme pigments more effectively and increased the lightness of the washed meat. The washing techniques for Mechanically Deboned Chicken Meat (MDCM) have successfully removed fat, heme pigments and other water soluble compounds (Yang and Froning, 1992) and resulted in higher myofibrillar protein contents. Darker color resulting from the higher heme content of MDPM is undesirable in poultry products intended for the white meat market.

Normally, surimi is prepared from fish protein through double or triple washing of mechanically deboned fish to remove blood, lipids, enzymes and sarcoplasmic proteins (Vilhelmsson, 1997). The application of surimi technology to duck meat processing could provide a new means for increasing the value and utilization of duck meat. Surimi processing of duck meat has already generated considerable interest and has demonstrated its potential for the development of new poultry products. The objective of this study was to determine the

functional properties of duck meat exposed to different washing cycle treatments. Because studies on duck meat are limited, this paper will also explain the effect of water washing on the physicochemical properties of duck meat.

MATERIALS AND METHODS

Preparation of sample: The raw materials consisted of mechanically deboned and skinned meat obtained from 18-month-old local Java ducks. Single, double, triple and quadruple washing cycles were applied in this study. The deboned meat was ground through a 2-mm grinder plate; 2 kg of ground meat was saved as unwashed sample and the remainder was used to prepare single, double, triple and quadruple washing samples of 2 kg each. Cold water (4°C) was added at a ratio of 3:1 (v/w) water to ground meat. After mixing for 4 min in a homogenizer, the mixture was allowed to settle for 10 min. The topmost water layer was removed and the settled residue was filtered through a commercial sieve. The water remaining in the washed sample was squeezed out using a cotton cloth and a screw press. First washing cycle was done and repeated for the next washing cycle. The dewatered sample was packed in the polyethylene bags and kept frozen at -18°C prior to analysis.

Proximate analysis: Moisture, protein, fat and ash contents were determined in accordance with standard AOAC methods (2000). Protein determination involved a Kjeldahl assay (Nx6.25). Fat was determined by extracting samples in a Soxhlet apparatus using petroleum ether as a solvent. Moisture was quantified by oven-drying 10 g samples at 100-105°C overnight. Ash was determined after incineration in a furnace at 500-600°C.

Myoglobin content determination: The myoglobin content was determined by direct spectrophotometric measurement, as described by Chaijan *et al.* (2006). Myoglobin content was calculated from the millimolar extinction coefficient of 7.6 and a molecular weight of 16,111.

$$\text{Myoglobin content} = A \times 16,111 \times F \times W_s \times 7.6 \times 100 \quad (1)$$

(mg/100g mince)

Where, A = absorbance, F = dilution factor, W_s = weight of mince in gram.

Cholesterol content determination

Standard cholesterol: 100 mg of standard cholesterol (extra pure, QRëC™ Brand, C₂₇H₄₆OH) was diluted in 100 ml glacial acetic acid (stock). The stock was pipette into 5 test tubes (0.1, 0.2, 0.3, 0.4 and 0.5 ml). Glacial acetic acid was added into each of the test tube until volume reach 3 ml and 2 ml color reagent was added.

Control solution was prepared by mixing 3 ml glacial acetic acid with 2 ml color reagent and read at 490 nm (UV-160A Shimadzu, Japan).

Preparation of coloring reagent: The stock reagent was prepared by dissolving 10 g of FeCl₃.6H₂O in glacial acetic acid using a 100 ml volumetric flask. Prior to use, 1.0 ml of the stock reagent was transferred into a 100 ml flask and concentrated H₂SO₄ was added.

Analysis according to Bohac *et al.* (1984) with a slight modification: Two grams of sample were extracted in a Soxhlet apparatus using petroleum ether as a solvent. Fat was diluted with chloroform until 10 ml. 2 ml of mixture (fat and chloroform) was saponified using 10 ml ethanolic 12% KOH and 0.3 ml 3% pyrogallol solution. The mixture was incubated at 80°C for 15 min. After cooling, 5 ml of distilled water were added. The unsaponified matter was extracted with 2 x 10 ml hexane, which was removed from the final extract by heating in a water bath (45°C) to form dried extracts.

Spectrophotometric analysis: The dried extracts were re-suspended in 3 ml glacial acetic acid. 2 ml of FeCl₃ coloring solution were added and the resultant color was read at 490 nm. The absorption was compared against an external cholesterol standard and the cholesterol content was calculated using the following equation:

$$\text{Cholesterol (mg/100 g)} = (c \times 20 \times \text{DF} \times W) / (4 \times 100) \quad (2)$$

Where: c = concentration of cholesterol (from standard curve); DF = dilution factor and W = weight of sample (mg).

pH: The pH was determined using the method of Jin *et al.* (2007). The pH was measured using a digital pH meter (Microprocessor pH Meter, Model pH 211, Hanna Instruments, Mauritius).

Water holding capacity: The Water Holding Capacity (WHC) was determined using the method of Jin *et al.* (2007) with a modification. The WHC of samples were determined by homogenizing 20 g sample with 40 ml of distilled water by a Waring blender for 30 s. 20 g of aliquot of the homogenate was weighed into centrifugation tubes and thereafter centrifuged at 5°C at low speed (1000 g for 15 min). The WHC was determined as liquid loss and expressed as percentage of weight of liquid release. WHC % = (before centrifuge weight - after centrifuge weight)/(before centrifuge weight) x 100.

Gel preparation: Gel preparation was based on Rawdkuen *et al.* (2009)'s method with a slight modification. Sample was cut into small pieces with an

approximate thickness of 1 cm and then placed in a mixer (Robot Coupe Blixer Grinder, France). Salt (3%, w/w) was added. The mixture was homogenized for 4 min at 4°C. The paste was stuffed into cellulose casing with a diameter of 2.5 cm and both ends of the casing were sealed tightly. The paste was incubated at 36°C for 30 min, followed by heating at 90°C for 10 min in a water bath. After heating, all gels were immediately cooled in iced flakes for 25 min and stored at room temperature for 30 min prior to analysis.

Measurement of gel strength: Gel strength of sample was measured by punch test using TA-XT2 texture analyzer (Stable Micro Systems, Surrey, UK) equipped with a 5-mm cylinder plunger. The breaking strength represented as the load value (kg) at the breaking point when the gel was compressed at a crosshead speed of 30 mm/min (Nakamura *et al.*, 1998). Gel strength was determined by multiplying the breaking strength (kg) and deformation (cm). Data obtained from triplicate experiments were used to calculate the means and standard deviations.

Determination of expressible moisture: Determination of expressible moisture was based on method described by Rawdkuen *et al.* (2009).

Folding test: The sample batches were stuffed into 2.5 cm diameter casings and cooked with the same procedure as the preparation of gel. The gelled samples were sliced into pieces with 2.5 mm thickness and folded.

Point 5 or AA grade for no crack showing after folding twice

Point 4 or A grade for no crack showing after folding in half

Point 3 or B grade for crack gradually when folded in half

Point 2 or C grade for crack immediately when folded in half

Point 1 or D grade for breaks by finger pressure

Warner-bratzler shear test: Shear force was determined using method espoused by De Huidobro *et al.* (2005). The parameter recorded was the maximum shear force that is the highest peak of the curve, which is the maximum resistance of the sample to shearing.

Color measurement: The sample batches were stuffed into 2.5 cm diameter casings and cooked with the same procedure as the preparation of gel. The gelled samples were sliced into 5 mm thick. The color of gels was measured using a colorimeter (Minolta CM 3500d, Japan). The color reading includes lightness (L*), redness (a*) and yellowness (b*). Whiteness was

calculated as described by Park (1994) as follows:

$$\text{Whiteness} = 100 - [(100 - L^*)^2 + a^{*2} + b^{*2}]^{1/2} \quad (3)$$

Statistical analysis: The data from three replications were analyzed using one-way Analyses of Variance (ANOVA) and the Duncan test for multiple mean comparisons. The data was processed using SPSS version 17.0 and significance was defined at $p < 0.05$.

RESULTS AND DISCUSSION

Chemical compositions: The chemical compositions of samples exposed to different washing cycles are shown in Table 1. Overall, moisture content was significantly increased by washing, but it was slightly reduced after quadruple washing. An increase in moisture could be associated with the reduction of protein and fat content. These results correlate with those of Yang and Froning (1992), who reported that the protein and fat contents of mechanically deboned chicken meat were reduced after washing from 14.87-11.58% and 14.5-1.2%, respectively. Dawson *et al.* (1988) reported that an increase in the moisture content could be due to the pH effect. When the pH increases there would be an increase in the space between peptide chains resulting from repulsion between protein groups of like charges, allowing more water to enter and occupy the tissue (Dawson *et al.*, 1988). A reduction ($p < 0.05$) in the protein contents of samples was determined as a result of washing. This reduction in protein content was likely due to the loss of water-soluble proteins with washing and the higher moisture content of the final products (Shahidi *et al.*, 1992). Successive washing was also effective in removing fat from the sample. The lowest fat content (2.02%) obtained from the sample washed with the quadruple washing. The effective in fat removal was attributed to the density and polarity differences between ground meat and the washing solutions (Yang and Froning, 1992).

In the present study, a reduction of myoglobin content was also noted after washing. The quadruple washing ($p < 0.05$) exhibited the lowest myoglobin content (24.17 mg/100 g) than the other washing cycles. This result was similar to results reported by Jin *et al.* (2007), in which the myoglobin of chicken breast surimi that had been washed four times was much lower than that of surimi that had been washed twice (2.50-3.20 mg/g, respectively). In surimi processing, myoglobin plays an essential role in the degree of whiteness (Chen, 2002). Ochiai *et al.* (2001) suggested that a higher degree of whiteness in surimi could be achieved by removing as much dark muscle as possible. The cholesterol content was also significantly reduced by washing. With the removal of fat from the sample as a result of washing, there was also a decrease ($p < 0.05$) in the cholesterol content for all the washing cycles.

Table 1: Chemical compositions of unwashed and washed duck meat

Sample	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Myoglobin (mg/100 g)	Cholesterol (mg/100 g)
UW	74.55±0.24 ^a	13.23±0.17 ^b	5.40±0.13 ^a	2.91±0.04 ^a	54.05±1.29 ^a	45.91±1.97 ^a
SW	78.94±0.16 ^d	14.32±0.30 ^a	3.69±0.04 ^b	2.61±0.03 ^b	50.36±0.04 ^b	34.13±0.53 ^b
DW	83.93±0.02 ^b	12.97±0.12 ^b	2.21±0.06 ^c	2.03±0.07 ^d	41.02±0.05 ^c	32.82±2.27 ^b
TW	84.77±0.39 ^a	10.93±0.28 ^c	2.04±0.10 ^d	1.99±0.08 ^d	38.32±0.70 ^d	31.51±2.82 ^{b,c}
FW	83.38±0.10 ^c	9.91±0.34 ^d	2.02±0.01 ^d	2.40±0.06 ^c	24.17±0.40 ^e	28.65±1.99 ^e

Each value is expressed as mean±SD (n = 3).

^{a-e}Means indicated with different superscript letters differ significantly (p<0.05).

UW, Unwashing; SW, Single Washing; DW, Double Washing; TW, Triple Washing; FW, Quadruple Washing

Table 2: Physicochemical properties of unwashed and washed meat gels prepared with different washing cycle

Sample	Expressible moisture (%)	Gel strength (kg.cm)	Folding test	Shear force (kg)
UW	6.51±0.52 ^d	1.21±0.05 ^d	3.33±0.58 ^b	1.32±0.02 ^b
SW	7.31±0.48 ^d	2.18±0.14 ^a	3.33±1.04 ^b	2.42±0.04 ^a
DW	11.36±1.15 ^c	1.97±0.08 ^{ab}	5.00±0.00 ^a	2.40±0.24 ^a
TW	17.11±0.67 ^b	1.77±0.21 ^{bc}	5.00±0.00 ^a	2.45±0.21 ^a
FW	22.27±1.25 ^a	1.51±0.25 ^{cd}	4.83±0.29 ^a	2.60±0.09 ^a

Each value is expressed as mean±SD (n = 3).

^{a-e}Means indicated with different superscript letters differ significantly (p<0.05).

UW, Unwashing; SW, Single Washing; DW, Double Washing; TW, Triple Washing; FW, Quadruple Washing

Physicochemical properties: Table 2 shows the changes in the physicochemical characteristics of unwashed and washed gel samples as a result of washing. Washing increased the expressible moisture of the gel, and the higher expressible moisture indicated that the protein network of the gel possessed fewer water binding properties. Ramírez *et al.* (2007) reported that the expressible moisture of a food system had a property inversely associated with the water holding capacity. The higher expressible moisture of gel was closely associated with a poor gel matrix where gel matrices that could not imbibe water led to high water releases (Rawdkuen *et al.*, 2009). The gel strength of sample was reduced by washing. Successive washing treatments led to a decrease in myofibrillar proteins (actomyosin and myosin) responsible for gelation and simultaneously reduced the sarcoplasmic content (Babji and Kee, 1994). In the present study, single washed gel sample showed the highest value of gel strength (2.18 kg.cm) and thereafter reduced to 1.97, 1.77 and 1.51 kg.cm after successive washing with double, triple and quadruple washing, respectively. The improved characteristics of gels due to washing are likely due to the removal of tropomyosin, troponin and myosin light chain in the first two washes that may interfere with protein-protein interactions involved in gel formation (Baxter and Skonberg, 2008). Washing improved gel folding score. Nowsad *et al.* (2000) reported that a decrease in pH significantly resulted in the loss of textural qualities (gel strength, breaking strength, protein solubility, cooking yield, expressible moisture) and lower folding test scores. It could thus be concluded that an increase in the number of washings would increase the meat's pH and improve its folding score. Although only samples washed two and three times scored a

maximum (5) in the folding test, the results obtained showed that there were no significant differences between the DW, TW and FW samples. Shear or cutting force values increased with the number of washings but the results obtained evidenced no significant differences (p>0.05) between washing cycles.

Color characteristics: The pH, WHC and color of unwashed and washed samples are shown in Table 3. Washing increased the pH from 6.87 to about 7.33. This increase during the washing process was attributed to the removal of lactic acid (Zepeda *et al.*, 1993). Washing also seemed to reduce the WHC of the samples. In general, high pH, high protein content and low moisture content are closely related to a high WHC and shear force in meats (Jin *et al.*, 2007). In this study, washing reduced the protein content and increased moisture content, which apparently led to a decrease in WHC. However, after excessive washing, the WHC of the sample increased. This was evident in the sample washed four times. Such results might be due to the increase in pH. Yang and Froning (1992) reported that it is likely that the pH and ionic strength of some washing solutions improved protein hydration. In the present study, an increase in pH usually induced more openings between the myofibril filaments, thereby trapping more water.

It was found that washing improved sample color and whiteness. In the single and double washing processes, lightness and whiteness increased and redness decreased. In the triple and quadruple washing processes, however, the washed samples became significantly darker and redder. This lower lightness and whiteness might have been due to the oxidation of myoglobin or to resultant reduced brown metmyoglobin

Table 3: pH, WHC and color characteristics of unwashed and washed duck meat

Sample	pH	WHC (%)	Lightness (L*)	Redness (a*)	Yellowness (b*)	Whiteness
UW	6.87±0.01 ^d	68.90±0.17 ^a	52.90±0.35 ^{cd}	4.82±0.06 ^a	16.75±0.05 ^c	49.78±0.32 ^{bc}
SW	7.18±0.00 ^c	65.23±1.17 ^{bc}	53.37±0.31 ^{bc}	4.57±0.12 ^a	17.67±0.08 ^{ab}	49.93±0.27 ^b
DW	7.26±0.01 ^b	63.68±0.28 ^c	54.42±0.06 ^a	3.35±0.02 ^c	17.81±0.10 ^a	50.95±0.07 ^a
TW	7.33±0.01 ^a	63.52±0.18 ^c	53.86±0.23 ^{ab}	3.42±0.29 ^c	17.53±0.08 ^b	50.52±0.19 ^a
FW	7.33±0.00 ^a	66.90±2.47 ^{ab}	52.69±0.45 ^d	3.96±0.28 ^b	17.49±0.25 ^b	49.41±0.39 ^c

Each value is expressed as mean±SD (n = 3).

^{a-c}Means indicated with different superscript letters differ significantly (p<0.05).

UW, Unwashing; SW, Single Washing; DW, Double Washing; TW, Triple Washing; FW, Quadruple Washing

release (Mancini and Hunt, 2005). Kim *et al.* (1996) reported that the color of surimi can be improved by increasing washing cycle and washing time. However, our result demonstrated that washing two times is better than washing three or four times.

Conclusion: The chemical compositions and physicochemical properties of samples were affected by the number of washings. The chemical compositions of samples showed a decrease in protein, fat, myoglobin and cholesterol contents after washing, though moisture content seemed to increase. Washing increased the pH, expressible moisture, folding test score and shear force but reduced the WHC and gel strength of the samples. The color of the samples was only slightly influenced by the number of washings because the lightness and whiteness of samples became darker after three and four washings. It could thereby be concluded that a double washing represents the best method for producing value product from duck meat because it best preserved meat whiteness and lightness. However, future studies are necessary for the improvement of WHC and expressible moisture.

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