Acta Alimentaria, Vol. 46 (2), pp. 172–180 (2017)
DOI: 10.1556/066.2016.0007

EFFECT OF WASHING CYCLES ON THE QUALITY OF SURIMI-LIKE MATERIAL OBTAINED FROM MECHANICALLY DEBONED CHICKEN MEAT

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(Received: 20 April 2015; accepted: 18 August 2015)

The appropriate number of washing cycles for obtaining most of the surimi-like materials is not well defined in literature. The aim of this work was to investigate the influence of the number of washing cycles (one, two, or four) on the quality of surimi-like material obtained from mechanically deboned chicken meat (MDCM) using the bleaching method with sodium bicarbonate. The product was evaluated based on its chemical and physical characteristics. The chemical compositions of samples showed an increase in protein (45.7 to 89.9%, dry basis) and decrease in fat (49.1 to 7.0%, dry basis) contents, while the moisture content increased from 69.5 to 79.1% after four washing cycles. Washing diminished yield. Gel prepared with MDCM washed once showed the lowest gel strength (507.1 g.cm). It thereafter increased to 546.0 and 602.7 g.cm after double and quadruple washings, respectively. Higher content of myofibrillar proteins and higher whiteness were also obtained after successive washings. It was concluded that four washing cycles was the most appropriate method for producing surimi-like material from MDCM.

Keywords: mechanically deboned chicken meat, washing, bleaching

The process utilized for the production of surimi or surimi-like material involves repeated washing of minced meat with aqueous solution to remove sarcoplasmic proteins, inorganic salts, low-molecular weight substances, lipids, and blood components (Dewitt et al., 2007), concentrating myofibrillar proteins, which are bound by various kinds of interactions according to the species in use (Ortiz & Aguilera, 2004). Myofibrillar proteins play an important role in gel formation, improving gel-forming ability, decreasing protein denaturation during frozen storage, and enhancing colour and flavour. A substantial amount of muscle proteinases are also removed during the washing process, resulting in a less active washed mince.

Considering that the lipid content of the species influences the shelf-life of the products, the consumer's acceptance, and the method for surimi obtaining, it is important to reduce this content by sequential washings to avoid adverse effects on the surimi quality, as oxidized lipids interact with proteins, causing denaturation, polymerization, and changes in functional properties (Jin et al., 2007; Cortez-Vega et al., 2015). Due to the high lipid content of MDCM, adequate washing is required to prepare high quality surimi-like material. However, several washings may result in high hydration of mince, making the subsequent dehydration process more difficult (Bentis et al., 2005). Moreover, excessive successive washings may reduce chemical compositions of samples, e.g. in case of quadruple washing (Ismail et al.,

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2010), and may led to a decrease in myofibrillar proteins responsible for gelation, forming a poorer gel matrix (Rawdkuen et al., 2009).

Another aspect, important for the production of a high quality surimi-like material, might be related to the utilization of sodium bicarbonate during washing. Sodium bicarbonate improves the gelling properties of the MDCM (Smyth & O'Neill, 1997) and increases the extraction of sarcoplasmic protein in relation to the pure water. A 0.5% sodium bicarbonate washing solution has been reported as ideal to provide better heme pigment extraction due the solubilisation of the muscle sarcoplasmic proteins (Ensoy et al., 2004), resulting in a product with lower fat and lower pigment concentration, which are favourable characteristics in the manufacturing of further processed products. However, the ideal number of washing cycles for obtaining most of the surimi-like materials is still far from being agreed upon by researchers (Ensoy et al., 2004; Ismail et al., 2010; Ng & Huda, 2011). In this way, the aim of this work was to investigate the influence of the number of washing cycles on the quality of surimi-like material obtained from MDCM.

1. Material and methods

1.1. Mechanically deboned chicken meat (MDCM)

Fresh MDCM was supplied from a local poultry processing plant. It was transported under refrigerated conditions to our laboratory and kept at –18 °C before use. The MDCM was produced in 3 mm particle size using a meat-bone separator, operating at temperatures of inlet 6 °C and outlet 10 °C (Cortez-Vega et al., 2013).

1.2. MDCM surimi-like material

MDCM was washed in one (W1), two (W2), or four (W4) cycles utilizing in each cycle a washing solution (0.5% $NaHCO_3$):meat ratio of 4:1 (v/w), at temperature of 7 °C, for 10 min, according to the methodology described elsewhere (Cortez-Vega et al., 2013). All subsequent analyses were carried out in triplicate.

1.3. Proximate composition

Moisture, crude protein, crude fat, and crude ash contents were determined according to the methods described by AOAC (1995). Moisture was determined by the oven drying method at 105 °C until constant weight (method 950.46), protein by the Kjeldahl method (method 928.08), fat by the Soxhlet method (method 960.39), and ash by using the muffle oven technique (method 920.153).

1.4. Yield

Yield was calculated from the difference between the weight of whole muscle and ending mass of MSCM surimi-like material. Yield %=(whole muscle weight–surimi-like material weight)/(whole muscle weight)×100 (Jin et al., 2007).

1.5. pH

pH was measured using a digital pH meter. About 10 g of sample was cut into small pieces to which 50 ml of distilled water was added, slurry was made using a blender, and the pH was recorded (Smyth & O'Neill, 1997).

1.6. Myofibrillar protein

The procedure used to determine myofibrillar proteins was similar to that utilized by Jin and co-workers (2007). The protein concentration was determined by the biuret procedure described by Clark and Switzer (1977).

1.7. Water holding capacity (WHC)

Five grams of sample was weighed into centrifuge 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)×100 (Jin et al., 2007).

1.8. Texture

Texture analysis of the gels was carried out using a texture analyser, as previously reported (Benjakul et al., 2000). Analyses were performed at least in triplicate. The results were expressed as breaking force (g), deformation (mm), and gel strength (g.cm).

1.9. Colour

The colour [CIE L*(lightness), a* (redness), b* (yellowness)] of the samples was evaluated using a colorimeter, with measurements were standardized with respect to the white calibration plate. Five readings were made from the surface of samples. Whiteness as an index for the general appearance of the test samples was calculated according to Equation 1 (Park, 2000):

$$\text{Whiteness}=100-[(100-L^*)^2+a^{*2}+b^{*2}]^{0.5} \qquad (1)$$

1.10. Statistical analysis

The statistical analysis of the results was performed using the statistical one-way analysis of variance (ANOVA), followed by the Tukey's test using the Statistica v. 8.0 software.

2. Results and discussion

2.1. pH, water holding capacity (WHC), composition, myofibrillar protein, and yield

The results of the proximate composition of the MSCM obtained are presented in Table 1. The data is comparable with the literature for MSCM obtained from whole chicken, where averages for moisture (67.2%), proteins (41.7%, dry basis), and lipids (55.3%, dry basis) have been reported as 62.1% (Smyth & O'Neill, 1997), 67.7% (De Oliveira et al., 2014), 68.1% (Cortez-Vega et al., 2015), and 70.7% (Perlo et al., 2006) for moisture; 35.6% (Smyth & O'Neill, 1997), 36.8% (De Oliveira et al., 2014), 40.4% (Cortez-Vega et al., 2015), and 46.4% (Perlo et al., 2006) for protein, dry basis; and 49.5% (Perlo et al., 2006), 56.9% (De Oliveira et al., 2014), 58.0% (Cortez-Vega et al., 2015), and 62.5% (Smyth & O'Neill, 1997) for lipids, dry basis.

Table 1. pH, water holding capacity (WHC), proximate composition, myofibrillar protein, and yield of the MDCM surimi-like material obtained after different number of washing cycles

Treatment	pH	WHC (%)	Proximate composition				Myofibrillar protein (mg g^{-1})	Yield (%)
			Moisture (%)	Crude protein (%)*	Crude fat (%)*	Ash (%)*		
UW MDCM	6.59±0.02^{b}	nd	69.5±0.4^{d}	45.7±0.6^{b}	49.1±1.31^{a}	4.4±0.1^{a}	nd	-
W1	7.27±0.01^{a}	78.51±0.65^{a}	77.9±0.4^{c}	87.7±0.5^{a}	12.3±0.3^{b}	4.3±0.6^{a}	22.60±0.49^{b}	66.16±1.71^{a}
W2	7.28±0.02^{a}	79.12±0.17^{a}	78.5±0.5^{b}	87.8±1.4^{a}	8.4±0.5^{c}	4.1±0.9^{a}	23.22±0.55^{ab}	63.90±1.21^{a,b}
W4	7.29±0.02^{a}	79.38±0.22^{a}	79.1±0.4^{a}	89.9±0.6^{a}	7.0±0.3^{c}	4.0±0.1^{a}	24.08±0.52^{a}	61.94±0.87^{b}

UW MDCM: unwashed mechanically deboned chicken meat; W1: one washing cycle; W2: two washings cycles; W4: four washings cycles
Values are given as means±SD from triplicate determinations; ^{a,b,c,d}: Different letters in the same column indicate significant differences ($P<0.05$) between treatments; *: dry basis; nd: not determined

As the MSCM composition varies significantly in function of the raw material utilized (Cortez-Vega et al., 2015), consequently it will be reflected in the number of washings necessary for obtaining the surimi-like material and the quality of the final product. This is a case like of the spent hen and broiler minces obtained by Nowsad and co-workers (2000). These authors utilized breast and thigh muscles, removing external fats from the meat before mincing. Differently from the other cases, the obtained minces presented high protein (78.6 and 82.7%, dry basis, respectively) and low lipid (18.6 and 12.4%, dry basis, respectively) contents, with 76.2% and 74.5% of moisture, respectively.

Adequate moisture (about 78%), low crude fat, and high myofibrillar protein are required to make a high quality surimi (Uddin et al., 2006). The moisture content significantly ($P<0.05$) increased from 69.5 to 79.1%with the washing cycles (Table 1). These results are in agreement with those obtained by Ismail and co-workers (2010) with washed mechanically deboned and skinned duck meat. The moisture increase can be associated with the removal of sarcoplasmic protein and fat and with the pH increase, which generates repulsion between protein groups and the water entrapment by hydrophilic residues of myofibrillar proteins (Smyth & O'Neill, 1997). However, washing did not statistically increase pH and WHC of the samples ($P>0.05$) (Table 1).

The lipid content was significantly reduced to 8.4% (dry basis) ($P<0.05$) after two washing cycles (Table 1), whereas other authors obtained reduction in fat content up to 3.9 and 3.4% (dry basis), from spent hen and broiler, respectively, also after two washing cycles (Nowsad et al., 2000). The same behaviour was also reported for washed duck meat (Ismail et al., 2010) but not for washed chicken breast (Jin et al., 2007), which has much lower initial fat content compared to the other samples (Ismail et al., 2010). Adequate washing is important to reduce the high lipid content of MDCM (Jin et al., 2007).

The protein increased up to 78.5% (dry basis) after two washing cycles, but the content did not differ statistically ($P>0.05$) among the washing cycles, except from the raw material (Table 1), whereas other authors observed increase in protein content up to 92.5 and 92.6% from spent hen and broiler, respectively, also after two washing cycles (Nowsad et al., 2000). The higher protein concentration was expected due the higher initial protein content of the raw material, as underlined before.

The myofibrillar protein content of the surimi-like material obtained after one washing cycle was significantly different ($P<0.05$) from that obtained after four washing cycles (Table 1). The increase in the number of washing cycles augmented the myofibrillar protein content, especially with tap water, as previously reported for spent layer surimi-like material (Ensoy et al., 2004). However, the opposite was observed for duck surimi-like material (Ismail et al., 2010), suggesting that upon extensive washing, myofibrillar proteins can also become readily soluble and then lost. Other authors related that myofibrillar protein was not significantly different among two times and four times washed chicken breast (Jin et al., 2007).

The ash content decreased with the increasing number of washing cycles, however the difference was not statistically significant ($P>0.05$) (Table 1). Washing changes the mineral composition of the mince when the washing liquid contains minerals (Nowsad et al., 2000). After two washing cycles, ash content reached 4.1% (dry basis) (Table 1), whereas other authors observed ash contents of 3.8 and 4.7%, for spent hen and broiler, respectively, after two washing cycles (Nowsad et al., 2000).

One single washing cycle showed the highest washing yield, whereas washing in four cycles showed the lowest washing yield (Table 1). Washing yield decreased significantly ($P<0.05$) with the increasing number of washing cycles. Washing results in the weight loss of washed mince, because fat and components that are soluble in water are removed. Hence, as the number of washing cycles increases, more undesirable substances, such as pigments, blood, and fat, are removed (Ng & Huda, 2011).

2.2. Texture and colour

Texture and colour of samples exposed to different washing cycles are shown in Table 2. The lowest breaking force and deformation were found in the MDCM. The result agrees with other findings (Nowsad et al., 2000). Gels prepared with MDCM submitted to one washing cycle had increased these texture parameters, however the highest breaking force and deformation were found in the gels prepared with MDCM submitted to four washing cycles. Similar results were previously obtained with MDCM after three washing cycles. Cortez-Vega and co-workers (2012) reported breaking force of 946 g, deformation of 8.9 mm and gel strength of 838.2 g.cm, while Cortez-Vega and co-workers (2015) observed breaking force of 1003.4 *g,* deformation of 6.4 mm and gel strength of 645.8 g.cm

The changes in the mechanical properties with the increasing numbers of the washing cycles could be associated to a settling effect on the gel structure due to a pH increase (Nowsad et al., 2000), directly related to an increase in WHC of the gels as a result of the increase in the amount of entrapped water (Zorba & Kurt, 2006; Ramírez et al., 2007). This behaviour was not evidenced here for either pH or WHC, which did not vary significantly ($P>0.05$), however the effect on the gel structure is clearer when the increased moisture content is considered, as previously discussed. Gel prepared with MDCM washed once showed the lowest value of gel strength (507.06 g.cm) increasing to 546.01 and 602.69 g.cm after double and quadruple washings, respectively (Table 2).

The improved characteristics of gels due to washing are likely due to the removal of tropomyosin, troponin, and myosin light chain that may interfere with protein–protein interactions involved in gel formation (Baxter & Skonberg, 2008). It could thus be concluded that the increase in the number of washings increases the meat's pH and also improves the gel strength due the dissolution of sarcoplasmic proteins (Luo et al., 2010).

Whiteness is one of the most important factors in surimi quality. It was found that washing also improved sample whiteness (Table 2). In the single, double and quadruple washing processes, the colour parameter lightness increased while redness decreased. Yellowness did not vary statistically ($P>0.05$). A similar result was reported by Rawdkuen and co-workers (2009) for tilapia surimi and protein recovered using an acid-alkaline process. The lowest whiteness (54.39) found in MDCM submitted to one washing cycle was probably due to higher levels of oxidized heme proteins. Myoglobin is known to contribute to the redness of muscle. When myoglobin is replaced by myofibrillar proteins during washings, gel-enhancing ability is enhanced (Park & Park, 2007). It is in accordance with our own results that shown higher content of myofibrillar proteins (Table 1), higher whiteness, and increased texture properties (Table 2) after successive washings.

Table 2. Texture and colour of the MDCM surimi-like material obtained after different number of washing cycles

Treatment	Texture			Colour			
	Breaking force (g)	Deformation (mm)	Gel strength (g.cm)	L*	a*	b*	Whiteness
UW MDCM	500.5±13.85^{d}	6.28±0.02^{b}	314.3±4.0^{c}	53.63±0.09^{c}	2.51±0.10^{a}	6.51±0.17^{b}	52.92±0.22^{b}
W1	798.5±12.6^{c}	6.35±0.02^{a}	507.1±6.2^{b}	60.11±0.27^{b}	2.46±0.11^{a}	8.95±0.21^{a}	54.39±0.31^{b}
W2	858.5±21.1^{b}	6.36±0.03^{a}	546.0±1.6^{b}	74.61±0.19^{a}	2.31±0.17^{b}	9.01±0.16^{a}	67.16±0.35^{a}
W4	946.1±13.4^{a}	6.37±0.01^{a}	602.7±6.3^{a}	75.12±0.21^{a}	2.17±0.13^{c}	9.15±0.12^{a}	68.17±0.33^{a}

UW MDCM: unwashed mechanically deboned chicken meat; W1: one washing cycle; W2: two washings cycles; W4: four washings cycles.
Values are given as means±SD from triplicate determinations.
^{a,b,c,d}: Different letters in the same column indicate significant differences ($P<0.05$) between treatments

3. Conclusions

Chemical composition, yield, and physical characteristics of surimi-like material obtained from MDCM were influenced by the number of washing cycles. Washings decreased fat content, while increasing protein and moisture contents. Washing improved the texture (breaking force, deformation, gel strength) but reduced the gel yield of the samples. Higher content of myofibrillar proteins and higher whiteness were also obtained after successive washings. It was concluded that four washing cycles was the most appropriate method for producing surimi-like material from MDCM, due mainly to the reduced fat content and increased myofibrillar protein content.

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