PROCESSING, PRODUCTS, AND FOOD SAFETY

The Influence of Extraction and Precipitation pH on the Dry Matter Yield of Broiler Dark Meat

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ABSTRACT In recent years, demand for white meat products has resulted in excess supplies and depressed prices of leg meat in the United States. One approach to increasing the utilization of dark meat is to extract the pigments and fat to make the resulting product more acceptable for the production of further-processed meat products. To date, such technologies have been inefficient (low yields) or have resulted in products of limited use. Three replicate trials were conducted to determine the effects of extraction pH and precipitation pH on the wet and dry extract yields of boneless, skinless broiler leg meat. Broiler leg meat was chopped with added water and extracted by adjusting the pH to 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, and 12.0 while mixing. After determination of extraction yields, each extraction was adjusted to pH 3.8, 4.0, 4.2, 4.4, 4.6, 4.8, 5.0, and 5.2 to determine the effect of precipitate pH on total wet and dry yields. Dry yield increased with extraction pH and precipitation pH. However, the greatest yields, over 70%, were at extraction pH values above 10.5, which have been associated with the production of potentially harmful by-products. Combinations of extraction pH values between 9 and 10.5 and precipitation pH values above 4.4 resulted in dry yields of approximately 65%. These results indicate that pH extraction and precipitation may result in economically viable yields. Further research is needed to determine the optimal conditions of yield, composition, and functionality.

(Key words: broiler dark meat, meat extraction, pH modification)

INTRODUCTION

With the expansion of the broiler further processing industry over the past 25 yr, emphases have been placed on improved distribution and marketing of cut up poultry and the creation of value-added further-processed products. Most of this expansion has been in the utilization of deboned broiler breast meat, resulting in excess supplies and depressed returns of mechanically separated meat, giblets, and dark meat. The major problems with utilization of broiler dark meat and product development are appearance (color), which is well documented to affect consumer purchase selections and final satisfaction with poultry products (Froning, 1995; Fletcher, 1997), as well as higher fat content and poor shelf stability due to oxidative rancidity of the fat.

The increased availability of mechanically separated poultry meat (MDPM) in the early 1970s resulted in concerted research efforts to improve product quality and thereby increase its utilization in consumer products. Due to the nature of the product, which is high in heme and fat, rancidity and functionality were major issues (Froning and Johnson, 1973). Attempts were made to extract the functional proteins and remove excess fat and heme pigments by centrifugation (Froning and Johnson, 1973). Young (1975) solubilized and extracted the proteins of MDPM by using relatively mild ionic strength aqueous solutions at pH 7 and recovering the proteins by adjusting the pH to 4.5.

In the 1980s researchers examined the surimi process used in fish to remove excess pigment and fat from otherwise underutilized fish sources. The objective of the surimi process is to reduce fat, meat pigments, blood, and objectionable flavor components that may be used to form restructured seafood products (Lanier, 1986; Lee, 1986). An excellent review on surimi technology for poultry, red meat, and fish was edited by Kijowski (1994).

Similar technologies to extract the pigments and fat from MDPM with sodium bicarbonate have been investigated (Hernandez et al., 1986; Dawson et al., 1988; Yang and Froning, 1992). Although the process significantly reduces heme and fat and results in a lighter-colored product, the final product yields are low and are still

Abbreviation Key: MDPM = mechanically deboned poultry meat.
susceptible to oxidative rancidity (Dawson et al., 1989, 1990).

High pH extractions and low pH precipitations have been used to isolate, concentrate, and structure proteins from vegetable sources (Fletcher and Ahmed, 1977). Similar high pH extractions (pH of approximately 10.5) followed by acid precipitation have also been conducted on poultry and red meat residues and by-products to concentrate the protein fractions while still maintaining a fibrous structure (Jelen et al., 1979, 1982; Lawrence et al., 1982; McCurdy et al., 1986). High pH extractions are often associated with dramatic protein denaturation; however, extractions conducted at pH 10.5 or less are not associated with producing potentially dangerous compounds, such as lysino-alanine (Golan and Jelen, 1979; Lawrence and Jelen, 1982; Ozimek et al., 1986).

The recent excess of broiler leg quarters and dark meat and resulting low market price suggests the possibility of enhancing dark meat utilization by extracting and producing a highly functional, low fat, light-colored protein extract. However, a combination of higher yields and improved stability compared with those generated by the surimi process would have to be achieved. The purpose of this project was to examine the use of high pH extractions, ranging from pH values of 8.0 to 12, and low pH precipitations, ranging from pH values of 3.8 to 5.2, on the wet and dry extract yields from boneless, skinless broiler dark meat. This project focused on dry weight yield because this would be a dominant issue regarding economical use of such an extract.

**MATERIALS AND METHODS**

**Sample Preparation, Extraction, and Precipitation**

Broiler chicken rear halves or whole legs (thigh and drum) were obtained from commercially available processed birds. After the skin was removed, the meat was removed from the femur and tibia, trimmed of excess fat and connective tissue, frozen, and held at −20°C for extraction.

Approximately 400 g of raw meat was weighed and then minced for 10 min in a commercial-grade food processor with approximately 1 kg of ice. The resulting meat slurry was placed in a large mixing beaker, and the pH was adjusted to 4.2 with 0.5 M NaOH with constant mixing. Individual lots were adjusted to a terminal pH of 8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, or 12.0 for alkaline hydrolyses and protein solubilization. Immediately, the pH was slowly readjusted with 2 M HCl, while stirring, to a pH of 2.2 for acid hydrolysis and protein solubilization. The pH was then adjusted to 4.2 with 0.5 M NaOH, and the entire contents of the mixing beaker were centrifuged at a relative centrifugal force of 27,504 for 20 min. The lipid fraction was removed by aspiration, and the supernatant containing the water-soluble components was discarded. The precipitate was weighed (wet weight), and triplicate subsamples were dried at 98°C under vacuum for 24 h to determine the percentage of solids in the extract.

From each of the 9 pH extractions, approximately 5 g were accurately weighed and dispersed in 10 mL of distilled water, and the pH was adjusted to 3.8, 4.0, 4.2, 4.4, 4.6, 4.8, 5.0, or 5.2 with 0.5 M HCl or NaOH. The material was centrifuged at a relative centrifugal force of 7,461 RCF for 20 min, and the aqueous phase was decanted and discarded. The precipitate was weighed (wet weight), and triplicate samples at each pH were dried as previously described to determine the percentage of solids.

**Experimental Design and Statistical Analyses**

The entire experiment, from deboned meat through final product, was replicated 3 times. The 9 pH extraction treatments (8.0, 8.5, 9.0, 9.5, 10.0, 10.5, 11.0, 11.5, and 12.0) and 8 precipitate pH treatments (3.8, 4.0, 4.2, 4.4, 4.6, 4.8, 5.0, and 5.2) resulted in 72 extraction and precipitate treatment combinations. The triplicate solids measurements were averaged by treatment combination (total n = 216; 3 replication × 72 treatments).

The wet extract yield was determined by dividing the unadjusted wet precipitate (pH 4.2) weight by the raw meat weight and multiplying the result by 100. Dry extract yield was calculated by dividing the total precipitate dry matter (dry yield × precipitated weight) by the initial dry meat weight (dry raw meat × raw meat weight) times 100.

The wet precipitate yield was determined by dividing the wet pellet weight (after final centrifugation) by the initial meat weight times 100. The final dry precipitate yield was calculated by dividing the dry pellet matter (pellet weight × percentage dry matter) by the dry raw meat weight (raw meat weight × percentage dry matter) times 100.

The difference in wet and dry extract yields by extraction pH and the wet and dry yields for the 72 extraction pH by precipitate pH were analyzed using the ANOVA option of the GLM procedure of SAS software (SAS Institute, 1988). The model tested the main effects using residual error. Means were separated using the Duncan’s multiple range test option (SAS Institute, 1988).

**RESULTS AND DISCUSSION**

After the mincing with added water in the form of ice, to keep the meat slurry from heating up during chopping, the meat slurry was very viscous, which indicated protein extraction. As the pH was adjusted to the various extraction pH values from 8 to 12, there were
noticeable differences in appearance, viscosity, and odor. When the extraction pH was 11 or above, the slurry was less viscous and readily exhibited a distinct ammonia-based off-odor. It was assumed that this viscosity change and off-odor were due to alkaline-based denaturation of the protein to the point of deamination. This observation was consistent with work conducted by Lawrence and Jelen (1982), who reported that protein extractions above pH 10.5 result in the formation of unusual amino acids such as lysino-alanine. They also stated that extraction pH values below 11 should not produce material that would pose any unusual health hazards for the consumer.

The effects of extraction pH on wet and dry extract yields are presented in Table 1. Wet extract yield was inconsistent at pH 8.0 and 8.5, and the maximum yields were obtained at extraction pH of 9.0 and 9.5, after which the wet extract yield steadily declined. The wet extract yield represents the protein fraction that was least soluble at the precipitation pH of 4.2 and retention of some water-binding capability in the exposed areas of the protein molecules and entrapping water in the unfolded protein matrix. Thus the wet yields at the lower extraction pH values may represent the optimization of these characteristics. The steady decrease in wet yield above pH 9.5 may be due in part to fragmentation and precipitation of smaller protein fragments that have less ability to bind water on exposed binding sites as well as a less structured matrix in which loosely bound water could be entrapped.

In contrast to the wet extract yield, the dry extract yield showed a significant increase as extraction pH values increased (Table 1). Dry extract yields increased from approximately 70 to 81.4%. Because the dry extract yield would not reflect loosely bound water, the increased yields may support the observation that at the higher pH values favor some denaturation and protein fragmentation. There was a significant negative correlation between wet and dry yields (r = −0.243; P < 0.0005) supporting this observation. The highest dry yields were observed for the extraction pH values of 11.0, 11.5, and 12.0, which indicated that protein denaturation (as also evidenced by the distinct odor of ammonia) resulted in increased dry matter yield. The lowest dry extract yield was from the extraction pH of 8 and 8.5 with 71.9 and 69.6%, respectively. These extraction pH values would be closer to those reported in the previous work conducted using surimi technology. Intermediate yields, between 73.1 to 76.1% were obtained using extraction pH of 9 to 10.5.

The results for the combined extraction pH and precipitation pH on wet extract yields are presented in Table 2. In general, wet yields were most influenced by precipitation pH compared with extraction pH. Although there were significant effects on wet yield due to extraction pH as explained earlier, there were significant interactions with precipitation pH such that no consistent pattern was noted across the different precipitation pH values.

The highest wet yields exceeded 200% at the lowest precipitation pH values of 3.8 and 4.0, respectively (Table 2). The highest wet yields occurring at the lower precipitation pH values depend on the level of moisture. The influence of precipitate pH on the moisture levels in meat is attributed to repulsion between protein groups of like charge, resulting in an increase in the

<table>
<thead>
<tr>
<th>Extraction pH</th>
<th>Wet extract (%)</th>
<th>Dry extract (%)</th>
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<tbody>
<tr>
<td>8.0</td>
<td>129.6b</td>
<td>71.9</td>
</tr>
<tr>
<td>8.5</td>
<td>109.8f</td>
<td>69.6i</td>
</tr>
<tr>
<td>9.0</td>
<td>134.7a</td>
<td>73.2f</td>
</tr>
<tr>
<td>9.5</td>
<td>134.7a</td>
<td>73.0f</td>
</tr>
<tr>
<td>10.0</td>
<td>120.7c</td>
<td>74.9e</td>
</tr>
<tr>
<td>10.5</td>
<td>115.9d</td>
<td>76.1h</td>
</tr>
<tr>
<td>11.0</td>
<td>104.1c</td>
<td>80.1i</td>
</tr>
<tr>
<td>11.5</td>
<td>91.7g</td>
<td>80.3i</td>
</tr>
<tr>
<td>12.0</td>
<td></td>
<td>81.4i</td>
</tr>
</tbody>
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*–i Means within a row without a common superscript are significantly different (P < 0.0001).

n per mean = 24.
space between peptide chains. Increased size of these interstitial spaces would allow more water to enter and occupy the tissue (Hamm and Deatherage, 1960). As the pH of proteins was adjusted away from their isoelectric points, there was an associated increase in protein solubility or hydration of the protein resulting in higher moisture retention. As the pH treatments moved closer to the myofibrillar isoelectric point, moisture decreased due to a decrease in the space between protein filaments. These principals of the effect of precipitation pH on meat protein water-binding properties are well established. The isoelectric point of the myofibrillar proteins and of meat in general is reported in the 5.0 to 5.1 pH range (Pedersen 1978). The effect of NaCl has a marked effect on altering the isoelectric point to a more acidic pH due to a decrease in the space between protein filaments. Increased size of these interstitial spaces would allow more water to enter and occupy the tissue.

The results for the combined extraction pH and precipitation pH on dry matter yields were recovered with extraction pH values of 11.0 or above and with precipitate pH values of 4.2 and above. Because water binding is not a part of the yield, the dry matter yield reflects the relative accumulated effects of the extraction pH and precipitation pH on solubilization of native and denatured protein fractions. Thus, the highest yields are associated with the highest yielding extraction pH and the precipitation pH values closest to the aggregate isoelectric point of the extracted proteins.

The successful production and use of extracted meat proteins depends on economy of production (high yields), safety, composition (low in pigment and lipid), and functionality of the extract in further-processed meat products. These results indicated the relative efficiencies of various extraction and precipitation schemes only for the dry yield. Earlier work on applying surimi-based technologies to poultry meat proved to be inefficient relative to processing cost, yield, and product quality. The work reported by Lawrence and Jelen (1982) indicates that extractions at high pH (11 or above) are associated with production of potentially unsafe compounds and would probably not be suitable for food products.

These results indicated that relatively high yields, approximately 65% or above, can be achieved with a combination of extraction pH values between 9 and 10.5 and precipitation pH values of 4.4 and above. In these combined extraction and precipitation pH ranges, yield and safety may be optimized. Based on the wholesale market prices for skinless boneless leg meat of approximately one-fourth to one-third of the value of skinless boneless breast meat, these yields would potentially have economic value.

Because chemical composition and functionality are also critical issues for the possible commercial use of dark meat extracts, these results are important in providing practical limits for the economical extraction based on maximizing yield and avoiding potentially dangerous by-products. Further work is necessary to optimize yield within acceptable limits of composition and functionality.

**ACKNOWLEDGMENTS**

This study was supported in part by funds provided by state and Hatch funds allocated to the Georgia Agricultural Experiment Station and by funds supplied by the University of Bologna, Bologna, Italy. The authors express their appreciation to Nicole Bartenfeld (University of Georgia, Athens) for technical assistance.

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