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Histological and chemical characteristics of mechanically deboned meat of broiler chickens

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ABSTRACT

In evaluation of the suitability of mechanically deboned poultry (MDP) for use in food products, the functional properties of this meat must be taken into consideration. The basic principle of meat separation varies among machines which in turn could affect the functional properties of the MDP produced. The MDP used in this study was produced from broiler carcass, back, wings and necks after commercial cutting. Separation was mechanically performed on a "Beehive" separator, which separates muscular, adipose tissue and skin from cartilage, bone and lymphatic tissues ("offal products"). Histological examination was performed on histological slides, stained with haematoxylin and eosin. Also, analysis of the content of water, lipid, protein, ash and calcium was carried out. Average water content was highest in deboned carcass meat samples (69.14%). Total lipids (20.85%) were highest in deboned back and total proteins (15.57%) in the deboned carcass. In deboned wings the content of total ash was very high (1.65%) as well as the content of calcium (0.29%). In "offal products" the highest average water content was in the whole carcass (59.02%). Total lipids (11.56%) were highest in wings, total proteins (23.88%), total ash (20.19%) and calcium content (7.41%) were highest in the back. Results of chemical analyses confirmed the results of histological examination. This parallel histological and chemical analytic approach could give relevant insights into raw material content, which directly influences the quality of final products.

Key words: deboned meat, chicken, histology, chemical analysis

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Introduction

Reconstituted poultry meat as a source raw material, is connected to the production of formed minced meat and sausage products, appearing on the market as breaded products, frozen and thermally half processed products (FRONING, 1976; FRONING, 1981; BAKER and KLINE,1984; FJELD, 1988; MIELNIK et al., 2002).

The quality of products made from deboned poultry meat depends primarily on the raw material, and to a lesser extent on the hybrid line of broiler chickens and on the technological process of deboning. One of the major requirements of mechanically separated meat is the production of deboned meat pulp without bone particles, and of calcium content which is not harmful for the consumer (NAGY et al., 2007).

Using histological staining and stereological methods, products made of deboned and formed minced poultry meat can be analised.These are commercially known as chicken nuggets, chicken burgers, breast fillets and chicken frankfurters. Previous studies imply that product quality, the quality of source raw material and the technology of deboning and processing are interconnected (NEJEDLI et al., 1998; JELIĆ et al., 1999; HRASTE et al., 2000; NEJEDLI et al., 2000; NEJEDLI et al., 2003). Chicken carcasses and their commercial cut are often the source of raw materials for final products of deboned poultry meat. The aim of this study is to demostrate their importance as meat pulp components, using comparative histological methods and chemical analyses. The meat pulp quality affects the quality of the final products of deboned poultry meat. This correlation has been implied in earlier research (MIELNIK et al., 2002; JANJEČIĆ, 2006) which points out the importance of tissue component ratio in the meat mass. The same authors found that the yield of mechanical deboning ranges between 55-80% depending on the carcass and the parts used for deboning. The rest comprises “offal products”, which are used as raw materials in pet food production.

Two types of separators for meat processing are used in the meat industry. “Beehive” (Weiler, USA) separators use a continuous mechanical process and separate meat mass from bones in previously chopped pieces. This is defined as deboning. The other type of separators (“Protecon” - Stork, Netherlands) use a discontinuous process, and separation occurs by compression, which separates meat from bone tissue, which is defined as mechanical pressure deboning. STIEBING (1998) reports a process called “soft separation”, which is the separation of fascia and tendons from meat mass by compression using rotating cylinders.

In preparing emulsion type and non emulsion type products with mechanically deboned poultry (MDP), the food industry must be familiar of the functional properties of this meat. Food processing plants need to know the type of machine used in preparation to evaluate functional properties. Mechanically deboned meat must not be used for the production of dry-cured meat products. Mechanically separated poultry meat can be used only for the production of soft meat products, cooked meat products, roasted meat products, semi-preserves and canned meat products or for the production of semi-products (NAGY et al., 2007).

Materials and methods

Separation of meat from broiler chicken carcasses of the hybride line Hybro, at 36 days of age and average body mass of 1400 g, was performed using a "Beehive" separator (Weiler, USA). The device is designed to compress raw material through openings of different sizes on a cylinder, using an auger. It separates meat mass, i.e. muscular and adipose tissue and skin from the cartilage, bone and lymphatic tissue. These are classified as "offal products" and are not used for human consumption. Samples of deboned meat from the whole carcass as well as from commercially cut parts (back, wings and neck) and "offal products" were used for this study. Five representative samples of deboned meat and five representative samples of "offal products" were used for histological and chemical analyses. Each representative sample represents 100 kg of mechanically deboned poultry (MDP) and 100 kg of "offal products". The total mass of deboned meat and "offal products" was 1000 kg. For the purpose of histological analyses, the samples were fixed in 10% formalin, embedded in paraffin and cut on microtome into 8 μm thick slices. The slices were stained routinely with hemalaun-eosin, according to Mayer (ROMEIS, 1968). Light microscopy analyses of meat pulp and "offal products" samples were performed under a Nikon Microphot-FXA (Nikon Corporation, Tokyo, Japan) light microscope. The content of the muscular, connective, adipose, cartilage, bone and lymphatic tissue was analyzed within the histological samples of the meat mass and "offal products" of the whole carcass and its parts.

Chemical analyses of the samples included reference methods for determination of moisture content (ISO 1442:1997; Meat and meat products - Determination of moisture content), determination of total fat content (ISO 1443:1973; Meat and meat products - Determination of total fat content), determination of nitrogen content (ISO 937:1978; Meat and meat products - Determination of nitrogen content), determination of total ash (ISO 936:1998; Meat and meat products - Determination of total ash) and determination of calcium content using atomic absorption spectrometry (ISO 6869:2000; Determination of the contents of calcium, copper, magnesium, manganese, potassium, sodium and zinc. Method using atomic absorption spectrometry) The results were analyzed statistically using "Statistica 7.1 for Windows".

Results

Samples of meat pulp and offal products were analyzed histologically and chemically after the deboning separation process of chicken carcasses, back, wings and neck.

In the samples of deboned chicken carcass, the longitudinal and the cross sections of muscular tissue were dominant (Fig. 1). A low content of diffusely dispersed cartilage tissue could be found in the deboned chicken carcass. In the samples of carcass "offal products" clusters of cartilage tissue and some bone tissue could be seen. Connective and muscular tissue comprised the largest part of the researched sample. Lymphatic tissue was also detectable.

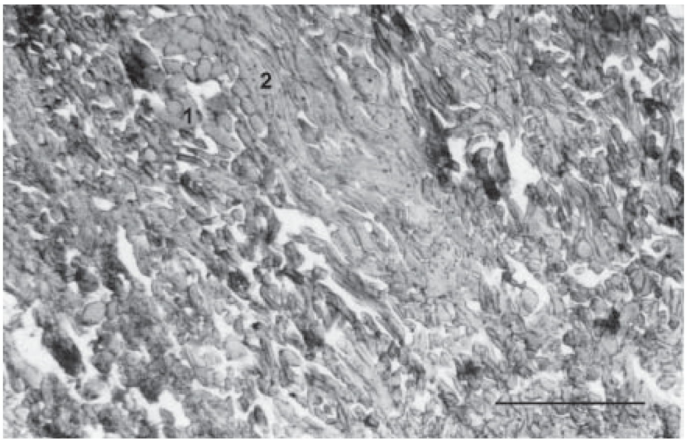

Fig. 1. Chicken carcass (deboned meat); 1-cross sections of muscular tissue, 2-longitudinal sections of muscular tissue, H&E; 4×2; scale bar = 500 μm.

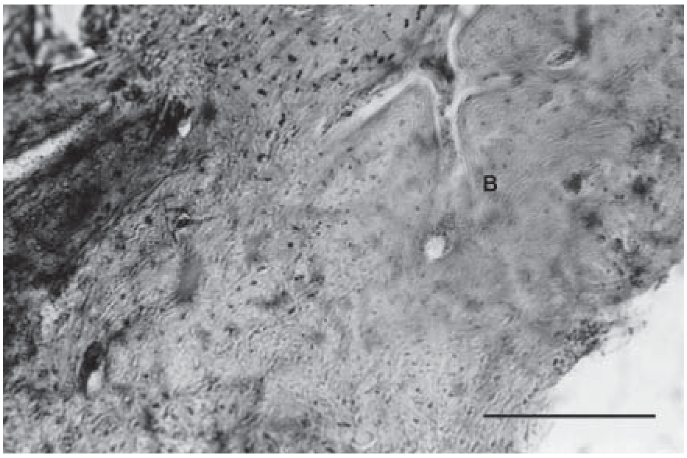

Fig. 2. Chicken wings ("offal products"); B-bone tissue. H&E; 10×2; scale bar = 200 μm.

Deboned samples of chicken back besides muscular and connective tissue contained cartilage and adipose tissue while samples of chicken back “offal products” had higher portion of cartilage and bone tissue.

A high content of muscular, adipose and connective tissue, as well as hyaline cartilage was noted in deboned chicken wing samples. In contrast, samples of chicken wing “offal products” had a higher proportion of bone and cartilage tissue, while the content of muscular tissue was lower (Fig. 2).

Deboned samples of chicken neck had a high content of muscular tissue and low content of connective tissue, bone and cartilage. On the other hand samples of chicken neck «offal products» had a high content of bone and cartilage, and a low content of muscular tissue.

Tabe 1. Water, lipid, protein, ash and calcium content in deboned meat of chicken carcass, back, wings and neck with descriptive statistical values (%)

Deboned meat	Mean	Median	Min.	Max.	SD	SE
CARCASS						
Water	69.14000	69.20000	68.40000	69.70000	0.512835	0.229347
Lipids	12.40000	12.40000	12.10000	12.70000	0.223607	0.100000
Proteins	15.57400	15.45000	15.32000	16.20000	0.356202	0.159298
Ash	0.40600	0.41000	0.39000	0.42000	0.012942	0.005788
Calcium (Ca)	0.06000	0.03800	0.03500	0.15000	0.050364	0.022523
BACK						
Water	60.31000	60.20000	59.70000	60.90000	4.237098	1-894888
Lipids	20.85000	21.05000	19.80000	21.40000	0.614410	0.274773
Proteins	13.46000	13.50000	13.05000	13.70000	0.248495	0.111131
Ash	1.18000	1.15000	1.10000	1.30000	0.090830	0.040620
Calcium (Ca)	0.19500	0.20500	0.15000	0.22000	0.027386	0.012247
WINGS						
Water	61.54000	61.90000	59.60000	62.30000	1.110405	0.496588
Lipids	19.47000	19.55000	19.10000	19.70000	0.233452	0.104403
Proteins	14.56400	14.50000	14.14000	15.10000	0.427645	0.191249
Ash	1.65600	1.60000	1.53000	1.80000	0.125020	0.055911
Calcium (Ca)	0.29360	0.29500	0.25600	0.31700	0.023692	0.010595
NECK						
Water	51.01000	49.90000	49.10000	55.50000	2.587566	1.157195
Lipids	6.29000	6.25000	5.90000	6.70000	0.292404	0.130767
Proteins	14.89200	14.90000	14.60000	15.19000	0.217187	0.097129
Ash	1.37000	1.40000	1.30000	1.45000	0.067082	0.030000
Calcium (Ca)	0.21600	0.21500	0.20000	0.23000	0.011937	0.005339

The content of water, lipids, proteins, ash and calcium was studied in deboned meat and "offal product" samples of chicken carcasses, back, neck and wings. Average water content was highest in deboned carcass meat samples (69.14%), slightly lower in samples of deboned wings (61.54%) and back (60.31%), and lowest in deboned neck meat samples (51.01%) (Table 1). The average proportion of total lipids was highest in deboned meat of chicken backs (20.85%), slightly lower in deboned meat chicken wings (19.47%), and the lowest in meat samples of deboned necks (6.29%), while in meat samples of deboned chicken carcasses it was 12.40%.

The lowest total ash content was detected in deboned meat samples of chicken carcasses (0.40%), while these contents in deboned meat samples of back, wings and neck were 1.18%, 1.65% and 1.37%, respectively.

Table 2. Water, lipid, protein, ash and calcium content in "offal products" of chicken carcass, back, wings and neck with descriptive statistical values (%)

Offal Products	Mean	Median	Min.	Max.	SD	SE
CARCASS						
Water	59.02000	59.10000	58.50000	59.30000	0.321325	0.143701
Lipids	9.51000	9.50000	9.30000	9.70000	0.151658	0.067823
Proteins	18.52000	18.50000	18.40000	18.70000	0.115109	0.051478
Ash	12.66000	12.65000	12.55000	12.80000	0.096177	0.043012
Calcium (Ca)	6.436000	6.400000	6.32000	6.57000	0.117175	0.052402
BACK						
Water	47.99000	48.10000	47.50000	48.35000	0.317017	0.141774
Lipids	7.74000	7.90000	7.20000	8.20000	0.461519	0.206398
Proteins	23.88000	23.80000	23.35000	24.40000	0.439602	0.196596
Ash	20.19600	20.16000	20.10000	20.40000	0.117175	0.052402
Calcium (Ca)	7.41000	7.50000	7.10000	7.60000	0.207364	0.092736
WINGS						
Water	57.47000	57.50000	57.10000	57.80000	0.277489	0.124097
Lipids	11.56000	11.60000	11.10000	11.90000	0.320936	0.143527
Proteins	18.32000	18.34000	17.96000	18.80000	0.322180	0.144038
Ash	9.45800	9.57000	9.17000	9.70000	0.233174	0.104278
Calcium (Ca)	3.36800	3.40000	3.10000	3.68000	0.247629	0.110743
NECK						
Water	46.35000	46.30000	46.10000	46.70000	0.217945	0.097468
Lipids	4.87000	4.85000	4.70000	5.10000	0.148324	0.066332
Proteins	21.12800	21.15000	20.98000	21.25000	0.098843	0.044204
Ash	16.88000	16.75000	16.58000	17.57000	0.406755	0.181907
Calcium (Ca)	7.07400	7.14000	6.81000	7.17000	0. 149766	0.066978

The average proportion of proteins in samples of chicken carcasses was not significantly different from the proportions in its parts. The content of proteins were just slightly higher (15.57%) in deboned meat samples of chicken carcasses, while in samples of deboned meat of wings, back and neck these portions were 14.56%, 13.46% and 14.89%, respectively.

The lowest calcium content detected by chemical analysis was in samples of deboned chicken carcass meat (0.06%), slightly higher in deboned meat samples of back (0.19%) and neck (0.21%), and the highest in wing samples (0.29%).

Table 2 shows the content of water, lipids, proteins, ash and calcium in “offal products”, determined by chemical analyses. The highest water content was detected in “offal products” from the whole carcass (59.02%), and a little less in wing samples (57.47%), while the lowest water content was detected in neck (46.35%) and back samples (47.99%). Average lipid content was lowest in neck samples (4.87%), slightly higher in back (7.74%) and whole carcass (9.51%) samples, and the highest in wing “offal products” samples (11.56%).

Analyses of total protein content showed higher values in back (23.88%) and neck (21.12%) samples, and lower and almost the same values in carcass (18.52%) and wing (18.32%) samples. Chemical analyses showed that the highest ash content was in back samples (20.19%), slightly lower in neck (16.88%) and whole carcass (12.66%) samples, while lowest in wing (9.45%) samples. Calcium content was highest in back (7.41%) samples, lower in neck (7.07%) and whole carcass (6.43%) samples, and the lowest in wing (3.36%) samples.

Discussion

Histological analyses of meat mass gained by the deboning process showed that muscular tissue dominated with the occasional appearance of cartilage, connective and lipid tissue. In “offal products” samples, cartilage and bone tissue were dominant, with the presence of connective, muscular, lipid and lymphatic tissue. According to TREMLOVÁ et al. (2006), mechanically deboned meat is a relatively non-standardized raw material which, despite its higher calcium (bone) content, has the structural characteristics of minced meat, and because of this it is easily incorporated into meat processing technologies. Application of mechanically deboned chicken meat in the production of formed minced meat and sausage products is well documented (DHILLON and MAURER, 1975; FRONING, 1976; JONES, 1986). It indicates that mechanically deboned chicken meat, because of its nutritive and functional characteristics, is appropriate for the design of different meat products.

According to our results, in samples of meat pulp of deboned chicken carcass, muscular tissue was dominant, while cartilage tissue was partially represented. This is understandable, because a significant part of the carcass mass is formed by muscles, primarily the breast muscles. As a result bone particles were not recognized in histological samples of the whole carcass meat pulp, and according to NAGY et al. (2007) they may account for up to 1.5%, with a maximum size of particles of 1.3 mm. The same authors indicate that mechanical separation could modify the structure of muscular fibers. This fact is confirmed by our photomicrographs, where partially preserved muscular fibers were observed in cross and longitudinal sections (Fig 1).

The prevalence of muscular tissue is indicated by chemical analysis, which confirms the highest total protein portion in deboned carcass meat (15.57%) compared to deboned meat of the back, wings and neck. It is known that water content is significantly higher in muscular tissue. This is confirmed in our study by the chemical analysis of deboned carcass meat (Table 1) from which it may be seen that water content is expectedly high (69.14%), and lipid content low (12.40%). Results of the chemical analyses of total protein (14.2%), water (60.1%) and lipids (26.2%) content in deboned whole carcass meat pulp of laying hens at the end of production (GRUNDEN et al., 1972) are partially confirmed by our results for deboned broiler chicken meat. The higher relative water content in the deboned meat of broiler chicken carcass compared to deboned carcass meat of laying hens at the end of the production cycle may be explained by the "ripened" meat of laying hens that results in lower water content. The same levels of total protein content and significantly lower lipid content in deboned broiler chicken carcass meat pulp compared to laying hens at the end of production, could be confirmed by fact that up to 35 days of age the mass gain of broiler chickens is based mostly on protein synthesis, and later on lipid deposition (NOVAK et al., 2004).

In histological slides of chicken carcass "offal products", samples show hyaline cartilage in the form of plates, which could be found, together with small pieces of bone, connective and muscular tissue and solitary clusters of lymphatic tissue. The higher content of cartilage, bone and connective tissue is confirmed by chemical analyses, which shows that the total protein and calcium ratio compared to "offal products" of back, wings and neck is relatively high (18.52% and 6.43%).

Histological analysis of deboned neck meat samples reveals a high content of muscular tissue, some connective tissue, cartilage and bone tissue. The high content of muscular tissue is confirmed by chemical analyses, which also shows the relatively low content of lipids (6.29%) which is not in agreement with the results of GRUNDEN at al. (1972). These autors found 27.2% of total lipids in deboned meat from the back and neck of broiler chickens, but they did not remove the skin and subcutaneous tissue. Histological slides of "offal products" of chicken neck show significant content of cartilage and bone tissue with relatively low content of muscular tissue, and was indicated by relatively high calcium content (7.07%).

Values of total proteins content in deboned meat from back and neck of broiler chickens are congruent with results of PARKES and MAY (1968) and FRONING (1970). Histological slides of deboned wing meat indicate the presence of muscular, adipose, connective and dispersed cartilage tissue. The relatively high content of total lipids in the meat pulp was confirmed by chemical analysis. Chemical analysis of wing "offal products" shows high calcium levels, and is proved by histological slides in which high bone and cartilage content and low muscular tissue content was found.

A comparison of histological and chemical analyses of the samples of deboned meat and "offal products", obtained by mechanical separation, proved that the use of the described methods offers reliable insight into the composition of the raw material and the quality of the final products. Such research could offer a new concept for the meat industry in terms of designing and developing new products based on deboned poultry meat. The use of model systems may be used to evaluate the functional properties of mechanically deboned meat, particulary MDP, from various deboning machines: emulsifying capacity, water holding capacity, emulsion stability, cooking losses, texture measurement for frankfurters and meat patties. Chemical, histological, functional, physical and sensory properties can provide beneficial information regarding the nature of mechanically deboned meat and its use in food products. However, it is important to exercise caution when extrapolating results from model systems to the performance of the meat in food products.

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SAŽETAK

U procjeni mehanički iskoštene peradi (MDP), a u vezi s namjenom kao sirovine za prehrambene proizvode, moraju se promatrati njihove funkcionalne vrijednosti. Osnovno načelo separacije mesa ovisi o svrhovitosti strojeva za separaciju koji mehanički iskošteno meso pripremaju za proizvode u smislu djelotvornih vrijednosti. Mehanički iskošteno meso peradi u ovom radu bilo je proizvedeno od pilećih trupova, krila i vratova nakon komercijalnoga rasjeka. Separacija je provedena na stroju „Beehive“ koji je iskoštio mišićno i masno tkivo te kožu, odvojeno od hrskavice, kosti i limfatičkoga tkiva (nusproizvodi). Histološka su pretraživanja obavljana na mikroskopskim preparatima obojenim hemalaun-eozinom. Kemijskom analizom određen je sadržaj vode, masti, bjelančevina, pepela i kalcija. Srednja vrijednost sadržaja vode bila je najviša u uzorcima iskoštenoga trupa (69,14%). Ukupne masti (20,85%) bile su najviše u iskoštenom mesu leđa, ukupne bjelančevine (15,57%) u iskoštenom mesu trupa. Sadržaj pepela bio je najviši u iskoštenom mesu krila (1,65%), kao i sadržaj kalcija (0,29%). U “nusproizvodu” najviša vrijednost udjela vode bila je u trupu (59,02%). Ukupne masti (11,56%) bile su najviše u “nusproizvodu” krila, a ukupne bjelančevine (23,88%), pepeo (20,19%) i kalcij (7,41%) bili su najviši u leđima. Rezultati kemijskih pretraga u korelaciji su s rezultatima histoloških ispitivanja. Takve uzajamne histološke i kemijske pretrage daju relevantne rezultate u smislu funkcionalnih komponenata sirovine koje izravno utječu na kakvoću završnoga proizvoda.

Ključne riječi: iskošteno meso, pilići, histologija, kemijska analiza