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EFFECT OF FROZEN STORAGE ON ALTERATIONS IN LIPIDS OF MECHANICALLY DEBONED CHICKEN MEATS

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Abstract

Composition (moisture, protein, fat, ash, fatty acids, collagen, cholesterol, calcium, iron and phosphorus contents) and rancidity related lipid changes in mechanically deboned chicken meats (MDCM) from back (MDBAM), breast frame (MDBFM) and neck (MDNM) were evaluated over 120 days of frozen storage at -18 °C. Type of MDCM was a significant factor affecting the composition, and hydrolytic and oxidative rancidity generation ($P<0.05$). Significant decreases ($P<0.05$) in linoleic acid of MDBAM and MDNM, and arachidonic acid of only MDBAM were observed over the 120 days of frozen storage. While MDBAM appeared to be more sensitive to lipid oxidation, MDNM showed greater lipid hydrolysis.

Keywords: Mechanically deboned chicken meats, composition, lipids, rancidity, frozen storage

MEKANİK AYRILMIŞ TAVUK ETLERİNDE DONMUŞ DEPOLAMANIN LİPİTLERDEKİ DEĞİŞİME ETKİSİ

Özet

Çalışmada mekanik ayrılmış tavuk sırt (MDBAM), göğüs (MDBFM) ve boyun (MDBNM) etlerinin bileşimi (kuru madde, protein, yağ, kül, yağ asitleri, kollagen, kolesterol, kalsiyum, demir ve fosfor içeriği) ve lipitlerindeki değişiklikler -18 °C'de 120 günlük donmuş depolama boyunca değerlendirilmiştir. Mekanik ayrılmış tavuk eti çeşidinin, mekanik ayrılmış etin besin öğeleri bileşimi ile lipitlerindeki hidrolitik ve oksidatif değişimlere önemli düzeyde etkili olduğu belirlenmiştir ($P<0.05$). Donmuş depolama boyunca MDBAM ve MDBNM'nin linoleik asit içeriğinde ve MDBAM'nin araşidonik asit içeriğinde önemli düşüşler gözlenmiştir ($P<0.05$). Donmuş depolanan MDBAM'de, lipitlerdeki değişim lipit oksidasyonundan kaynaklanırken, MDBNM'nin lipitlerindeki değişime lipit hidrolizinin neden olduğu belirlenmiştir($P<0.05$).

Anahtar kelimeler: Mekanik ayrılmış tavuk eti, bileşim, lipitler, ransidite, donmuş depolama

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INTRODUCTION

Poultry meat consumption continues to increase all over the world with a change in buying behavior and consumption attitudes from whole carcass to cut-up parts and further processed poultry products. The growing demand for cut-up parts and further processed convenience products has provided poultry processors significant amounts of leftover parts on the carcass to be used for mechanical deboning (1-3). Mechanically deboning, an efficient method of salvaging meat from parts left on carcass after hand deboning and from poor quality poultry, is generally accomplished by grinding meat and bone together and by forcing the mix through a fine screen or slotted surface in order to eliminate bone particles (1, 3-5).

This valuable co-product of poultry meat processing has been usually utilized in comminuted meat products formulations such as frankfurters, fermented sausages and restructured chicken products as substitution of the meat raw material due to its smooth consistency, good nutritional and functional characteristics, and low cost (1, 3, 5-8). Nevertheless, extreme mechanical stress and aeration during processing, and its high bone marrow, heme pigment and lipid contents promote lipid oxidation and makes mechanically deboned meat (MDM) very prone to onset of oxidative rancidity, which could result in deterioration of quality during storage and have significant influence on the stability of final product formulated with deboned material (1, 8-10). Polyunsaturated fatty acids (PUFAs), especially linoleic and arachidonic acids, of meat are subjected to lipid oxidation yielding secondary oxidation products responsible for off-flavor and off-odor generation and potential toxicity (1, 11-13).

Hydrolytic rancidity is another type of rancidity which could cause quality loss in MDM (12, 14) as it generally has high moisture content and microbial load (15). Lipolytic enzymes of microbial and muscle origin initiate hydrolytic changes involving hydrolysis of triacylglycerol molecules to first diacylglycerols, then monoacylglycerols and free fatty acids in meat fats (12,16). Free fatty acids generated as a result of hydrolysis could have direct effects on aroma of the product and could combine with sodium ions to form soaps and impart soapy aroma (16).

Deteriorative changes due to rancidity generation during storage of meat and meat products are of great economic importance to both consumers and processors (17). Therefore, the purpose of the current study was to evaluate rancidity related alterations in lipids of mechanically deboned chicken meats (MDCMs) of different origin during frozen storage.

MATERIALS AND METHODS

Three different types of MDCMs produced after removal of usable parts separated from freshly slaughtered chicken carcasses were kindly donated by a commercial chicken meat processing plant, BEYPİLİÇ, located in Bolu, Turkey. These three MDCMs originated from back (dorsal part of the carcass), bone neck and breast frame meat. A POSS PDX-5 deboning machine (Canada) was used in processing of MDCMs with an adjustment to about 75%±5% yield. Three different batches of MDCM that were mechanically deboned breast frame meat (MDBFM), mechanically deboned back meat (MDBAM) and mechanically deboned neck meat (MDNM) were separately weighed into 1000 g portions, and vacuum-packed in polyethlene pouches having an oxygen permeability of 45 cm^3/m^2/24 h/690 mmHg (at 25 °C and 0% RH) followed by freezing at -30 °C. MDCM batches were then stored at -18 °C for 120 days for further analysis. Samples were analyzed at 0, 30, 60, 90 and 120^{th} days of frozen storage at -18 °C. MDCM were thawed at 4 °C for 24 hours before use for analysis.

Compositional analyses

Initial moisture, protein (Nx6.25), fat, ash, calcium, iron and phosphorus contents were determined in duplicate for each sample following AOAC methods (18). Collagen protein (hydroxyprolin) was estimated following the methods reported by Aktan (19) and Yang and Froning (20) with slight modifications.

Initial cholesterol content was determined using the method reported by Rudel and Morris (21). Total lipids of MDCM were extracted with chloroform:methanol (2:1) using a sample:solvent ratio of 1:2 (22). For cholesterol analysis, after saponification of lipids, cholesterol in the unsaponifiable fraction was detected spectrophotometrically.

Thiobarbituric acid value

Thiobarbituric acid (TBA) value was determined spectrophotometrically as mg malondialdehyde (MA) per kg sample using the procedure of Tarladgis et al. (23) at each period of frozen storage.

Free fatty acid

Free fatty acid (FFA) was determined by titrating 10 mL of the lipid extract dissolved in 20 mL of ethanol/diethyl-ether (1/1) with an ethanolic solution of 0.1 M KOH, using phenolphthalein as indicator. FFA was expressed as g of oleic acid/100 g of MDCM (18).

Fatty acid composition

For analysis of fatty acids at stages of frozen storage, triglycerides in the extracted lipid fraction extracted as described above were converted into the fatty acid methyl esters according to the AOCS Official Method Ce 2-66 (24). A Shimadzu 17A Gas Chromatography equipped with a flame ionization detector and SP2560 column (100mx0.25mmIDx0.20µm film thickness) (Supelco, Bellefonte PA) was used for determination of fatty acid composition. The initial temperature of 140 °C was maintained for 5 minutes, then raised to 240 °C at a rate of 4 °C/min and kept at 240 °C for 10 minutes. The split ratio was 1:100 and the carrier gas was helium. The injector and detector temperatures were 230 and 240 °C, respectively.

Statistical analysis

Data from two replications for each attribute were analyzed by analysis of variance with General Linear Models (GLM) procedure of SAS (25). Means were separated ($P<0.05$) using Least Significant Difference (LSD) procedure (25).

RESULTS AND DISCUSSION

Composition of MDCM

Composition of MDCM obtained from different parts of chicken carcasses is presented in Table 1. Type of MDCM was a significant factor affecting composition ($P<0.05$). It was reported that incorporation of skin tissues resulted in differences in lipid and protein contents of MDCM depending on the origin of raw material (26). The highest moisture content was determined in MDNM (74.95%) followed by MDBFM (68.82%) and MDBAM (59.05%), respectively. Parallel to the moisture content, MDNM had the lowest protein, fat and ash contents and the highest moisture to protein ratio ($P<0.05$). While MDBFM yielded the highest protein content (16.90%) within the MDCM tested, MDBAM possessed the highest fat (26.95%) and the lowest collagen (8.36% in total protein) contents ($P<0.05$). This higher fat content of MDBAM was likely due to high fat content of the tissue under the skin and more skin and bone marrow incorporation during processing. Negrao et al. (27) noted that MDCM possessed a relatively higher lipid and lower protein contents as compared with chemical composition of typical chicken muscle. Results obtained for the composition of MDCM in the current study were in agreement with the findings of previous studies (3, 17, 27-30).

Cholesterol contents of MDBFM, MDNM and MDBAM were 82.74 mg/100g, 82.34 mg/100g and 168.89 mg/100g, respectively (Table 1). This significantly higher ($P<0.05$) cholesterol content of MDBAM, which also had the highest fat content, could be attributed to more bone marrow, skin and residual offal incorporation into the product during processing. Al-Najdawi and Abdullah (4) noted that bone marrow, body fat and skin were major factors affecting cholesterol level in MDM.

It was previously reported that mechanical deboning generally resulted in increases in the minerals, calcium, iron and phosphorus in MDMs and additional calcium and iron in MDM is easily absorbed in human body (7, 31). Findings on minerals obtained in the present study supported this information. When the MDCM types were compared, MDBFM with the highest ash content had the greatest ($P<0.05$) calcium, iron and phosphorus contents as compared to MDNM and MDBAM (Table 1).

Fatty acid composition

Predominant unsaturated fatty acids in MDCM that might cause oxidation of lipids were oleic (C18:1), linoleic (C18:2), linolenic (C18:3) and arachidonic (C20:4) acids. Composition of fatty acids in MDMs differs depending on several factors such

as source of meat and the amount of meat and skin incorporated into the product during separation process (1-3, 13). These factors determine final fatty acid distribution of the final product (concentration of saturated and unsaturated fatty acids) and thus, affect degree of lipid oxidation, one of the measures of storage stability.

Among the total fatty acids determined in MDCMs, 21.52, 22.67, and 25.33% for MDBAM, MDBFM, and MDNM, respectively, corresponded

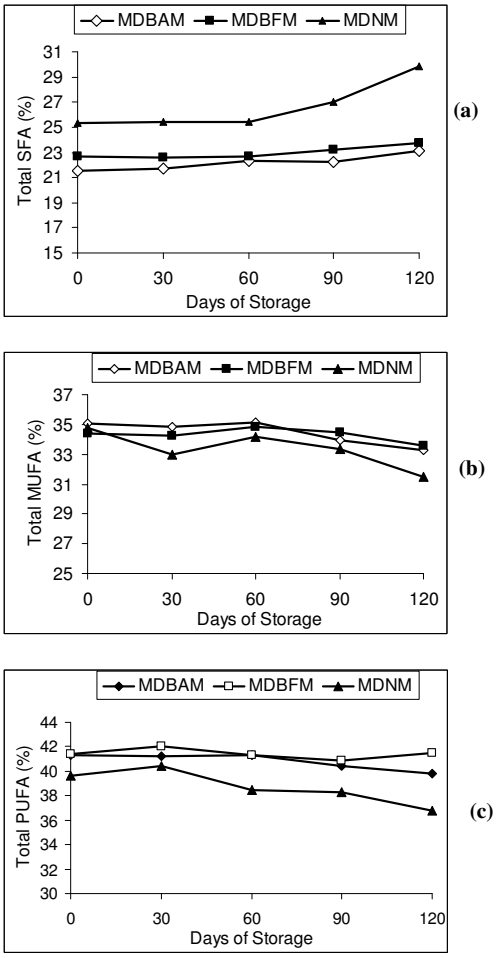

Figure 1. Changes in total SFA (a), MUFA (b) and PUFA (c) concentrations of MDCM during frozen storage

to saturated fatty acids (SFAs). Initial total SFA concentration of MDNM was significantly higher than the other types of MDCMs (P<0.05), which showed increases (P<0.05) over the 120-days of frozen storage (Figure 1). Palmitic acid (C16:0) was predominant fatty acid within the SFAs. MDNM contained higher palmitic and stearic acids (C18:0) as compared to MDBFM and MDBAM all over the storage periods (P<0.05).

Initial concentrations of total monounsaturated fatty acids (MUFAs) in MDBAM, MDBFM and MDNM were 35.04, 34.36 and 34.78%, respectively (Figure 1), of which oleic acid (C18:1) was the most abundant one. MDNM had lower oleic acid than the other two MDCM types (P<0.05). The highest initial palmitoleic acid (C16:1) was determined in MDNM (5.14%). While concentration of palmitoleic acid in all types of MDCMs showed significant decreases over the frozen storage, the most noticeable reduction in C16:1 was observed in MDNM (P<0.05).

Concentration of total PUFAs was higher than that of MUFA in all types of MDCM. Significant reductions in PUFAs during frozen storage over 120 days (P<0.05) were observed in MDCM with the exception of MDBFM (Figure 1). Predominant PUFA in MDCM was linoleic acid (C18:2) followed by linolenic (C18:3) and arachidonic (C20:4) acids (Table 2). MDNM had generally lower linoleic and linolenic acids than MDBFM and MDBAM (P<0.05) while MDNM and MDBFM contained higher arachidonic acid than MDBAM.

Lipid fractions of frozen foods undergo oxidative reactions (32) which are initiated in membrane bound lipids, and particularly unsaturated fatty acids such as those present in chicken, turkey and fish play significant role in this process (14, 33, 34) Püssa et al. (13) reported that PUFAs are highly susceptible to lipid peroxidation due to active bisallylic methylene groups in their molecules, and both linoleic and arachidonic acids containing two and four double bonds, respectively, mostly contribute to peroxidation process of PUFAs in MDMs. In the present study, significant decreases (P<0.05) in linoleic acid of MDBAM and MDNM, and arachidonic acid of only MDBAM were observed over the 120-day frozen storage (Table 2), which was in agreement with the findings of aforementioned study (13).

TBA value

TBA values determined to monitor lipid oxidation in MDCM over 120 day frozen storage are presented in Figure 2. Initial TBA values for MDBAM, MDBFM and MDNM were 0.23, 0.13 and 0.12 mgMA/kg, respectively. MDBAM possessing

the highest total lipid content had the highest TBA values than the other groups (P<0.05) during frozen storage. TBA values in all MDCMs showed increases over time and reached to 0.87, 0.76 and 0.69 mgMA/kg for MDBAM, MDBFM and MDNM, respectively, at the end of storage (Day 120). It was noted that disruption of muscle membranes integrity favors oxidation of unsaturated fatty acids resulting in free radical formation and propagation of oxidative reactions (35, 36). Final TBA values obtained for MDCM samples in the present study did not exceeded the threshold value (>1.0 mgMA/kg) for perceived undesirable rancid flavor and odor reported in the literature in meat products (23, 37), likely due to vacuum packaging of the samples which might have partially prevented oxygen transmission inside the package. Dawson and Gartner (28) suggested vacuum packaging for mechanically deboned poultry meat to minimize development of rancid flavor and accompanying TBA values. Pettersen et al. (2) noted that vacuum or modified atmosphere packaged mechanically deboned turkey meat samples had lower TBA values than air-packaged samples. Smith (38), Pikul and Niewiarowics (39), Abdel-Kader (40), Tubolyet al. (41) and Pettersen et al. (2) also reported that frozen storage resulted in increases in TBA value of MDMs.

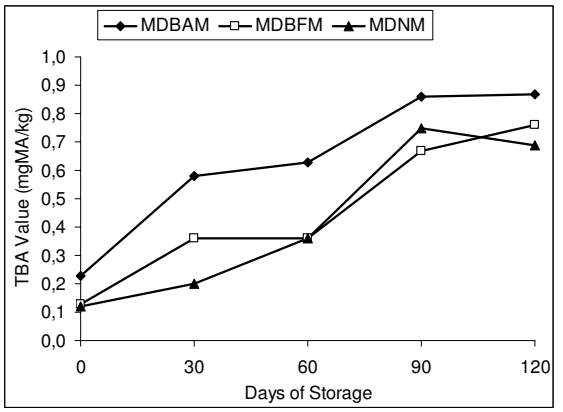

Figure 2. Changes in TBA values of MDCM during frozen storage

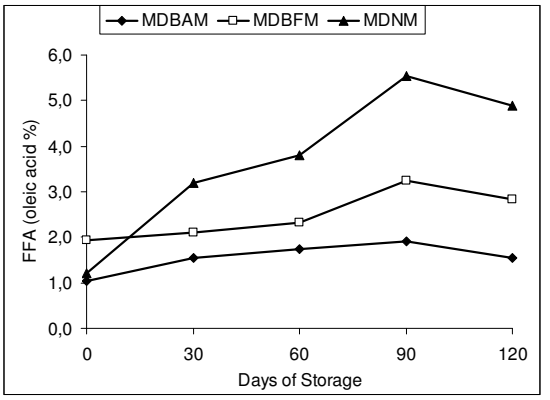

Figure 2. Changes in FFA values of MDCM during frozen storage

Free fatty acid

Initial FFA values for MDBAM, MDBFM and MDNM were 1.04%, 1.93% and 1.22% (% O.A.), respectively (Figure 3). Lipid deterioration in fatty foods is the main cause of reduced shelf-life due to progressive oxidation and enzymatic hydrolysis of unsaturated fatty acids (16,42). FFA value is the measure of hydrolytic rancidity resulting from accumulation of FFA due to lipolytic enzyme activity of microbial and muscle origin, which might impart undesirable flavor in foods (12, 16). The initial FFA values of MDBAM, MDBFM and MDNM (1.04, 1.93 and 1.22%, respectively) showed increases over time (P<0.05) reaching to 1.56, 2.82 and 4.89%, respectively, at the end of the frozen storage. In contrast to TBA value, MDNM with the highest total SFA and moisture contents, and the lowest PUFA/SFA ratio had the highest FFA values during 120 days of frozen storage. Similar to results obtained from the current study, Özkeçeci et al. (43) reported that FFA value showed increases with time in MDCMs stored at -20°C.

Table 1. Composition of mechanically deboned chicken meats (MDCM)

Attributes	Type of MDCM		
	Back	Breast	Neck
Moisture (%)	59.05^{b}	68.82^{ab}	74.95^{a}
Protein (%)	12.77^{b}	16.90^{a}	12.27^{b}
Fat (%)	26.95^{a}	12.34^{b}	11.59^{b}
Ash (%)	0.92^{b}	1.45^{a}	0.88^{b}
Collagen in total protein (%)	12.63^{a}	8.36^{b}	12.14^{a}
Cholesterol (mg/100g)	168.89^{a}	82.74^{b}	82.34^{b}
Ca (mg/kg)	520.70^{b}	1795.20^{a}	568.00^{b}
Fe (mg/kg)	16.10^{b}	33.70^{a}	20.60^{ab}
P (mg/kg)	2187.00^{b}	2959.4^{a}	2067.9^{b}

LS means in a row not having a common letter are different (*P*<0.05).

CONCLUSIONS

Composition of MDCMs, a valuable co-product of chicken meat processing, is influenced by several factors such as source (origin) of carcass part and processing with or without skin (skin incorporation). Our results confirmed that MDCMs are extremely susceptible to lipid deterioration during frozen storage due to high PUFA and heme pigment contents, finer particle size and elevated temperatures during processing. According to the results obtained from the present study, type of MDCM was a significant factor affecting rancidity generation in the product. MDBAM with the highest lipid content showed the greater lipid oxidation while MDNM appeared to be more sensitive to lipid hydrolyses.

Rancidity due to lipid deteriorations is one of the main factors limiting utilization of MDCMs in fur-

Table 2. Fatty acid composition of mechanically deboned chicken meats (%, in total lipid)

Type of MDCM		Storage periods (day)				
	Fatty acids	0	30	60	90	120
Back	C 14:0	0.70	0.65	0.64^{AB}	0.67^{AB}	0.65^{AB}
	C 16:0	5.71^{bC}	5.16^{bC}	15.25^{bC}	15.47^{bC}	16.56^{aB}
	C 16:1	4.94^{aAB}	4.58^{b}	4.27^{cB}	4.10c^{B}	4.19^{cA}
	C 18:0	5.11^{cB}	5.94^{b}	6.46^{a}	6.11^{bB}	5.88^{bC}
	C 18:1	30.10^{bA}	30.29^{abA}	30.86^{aA}	29.88^{bA}	29.06^{cA}
	C 18:2	35.64^{aA}	35.75^{aA}	35.75^{aA}	35.08^{bA}	34.58^{cB}
	C 18:3	4.72^{aA}	4.54^{abB}	4.63^{abA}	4.45^{b}	4.42^{bAB}
	C 20:4	0.99^{aB}	0.99^{a}	0.93^{abB}	0.90^{abB}	0.85^{bB}
	Others	2.09^{cA}	2.10^{cA}	1.22^{d}	3.34^{bA}	4.01^{aA}
Breast	C 14:0	0.62	0.51	0.57^{B}	0.58^{B}	0.56^{B}
	C 16:0	16.73^{aB}	16.17^{bB}	16.08^{bB}	16.25^{bB}	16.62^{aB}
	C 16:1	4.83^{aB}	4.11^{b}	4.01^{bB}	4.07^{bB}	4.15^{bA}
	C 18:0	5.32d^{AB}	5.95^{c}	6.07^{bc}	6.38^{abB}	6.58^{aB}
	C 18:1	29.53^{cB}	30.14^{bA}	30.80^{aA}	30.41^{bA}	29.39^{cA}
	C 18:2	35.41^{abA}	35.49^{abA}	35.18^{bB}	35.37^{abA}	35.74^{aA}
	C 18:3	4.74^{bA}	5.21^{aA}	4.71^{bA}	4.11^{c}	4.51^{bcA}
	C 20:4	1.32^{A}	1.31	1.45^{A}	1.40^{A}	1.23^{A}
	Others	1.50^{B}	1.11^{B}	1.13	1.43^{B}	1.22^{C}
Neck	C 14:0	0.79^{ab}	0.62^{b}	0.85^{aA}	0.80^{abA}	0.72^{abA}
	C 16:0	18.87^{A}	18.62^{A}	18.89^{A}	18.74^{A}	19.04^{A}
	C 16:1	5.14^{abA}	4.24^{c}	5.20^{aA}	4.71b^{A}	3.64^{dB}
	C 18:0	5.67^{dA}	6.15^{c}	6.17^{c}	7.48b^{A}	10.11^{aA}
	C 18:1	29.64^{aB}	28.72^{bB}	28.94^{bB}	28.65^{bB}	27.81^{cB}
	C 18:2	34.27^{aB}	34.41^{aB}	32.86^{bC}	32.78^{bB}	31.54^{cC}
	C 18:3	4.22^{bB}	4.68^{aAB}	4.17^{bB}	4.15^{b}	4.05^{bB}
	C 20:4	1.10^{AB}	1.36	1.43^{A}	1.33^{A}	1.15^{A}
	Others	1.20^{bB}	1.21^{bB}	1.49^{b}	1.36^{bB}	1.84^{aB}

a,b,c,d: Within a MDCM type, for an individual fatty acid (between storage days), LS means in a column not having a common letter are different ($P<0.05$).
A, B, C: Within a storage period, for an individual fatty acid (between MDCM types), LS means in a column not having a common letter are different ($P<0.05$).

ther processed meat products. Therefore, attempts to minimize rancidity generation with improved production and storage conditions would be helpful. Vacuum or modified atmosphere packaging and antioxidant addition might contribute higher quality product.

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