Influence of Mechanical and Hand deboning on Meat Properties of Whole and Skinned Spent Layers

by

Rula Awwad Al- Najdawi

عميد كلية الدراسات العليا

Supervisor

Dr. Basem Al- Abdullah

Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Food Science

Faculty of Graduate Studies

University of Jordan

April 1999

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This thesis was successfully defended and approved on April 28th, 1999.

EXAMINATION COMMITTEE	SIGNATURE
Dr. Basem M. Al- Abdullah, Chairman **Assis. Prof. of Food Science**	
Dr. Mohammed A. Humeid, Member **Prof. of Food Chemistry**	
Dr. Malik S. Haddadin , Member **Assis. Prof. of Food Science**	
Dr. Ali Dabash , Member **Prof. of Food Chemistry**	

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DEDICATION

All the success I reached and hoped to achieve in the years to come is by the help and blessing of our Mighty Allah so, thanks God, I'm so grateful.

To my father, the one to whom I owe every achievement in my life.

To my mother, the patient, caring and loving.

To you two I dedicate this work, with all my love, care and respect, without you with me I would never had it this way.

A special dedication to the soul of our late King of the hearts, King Hussein (may his soul rest in peace).

To my Brother and sisters, to my far away cousin Lana and all my cousins, and to all my family I attribute my thesis.

With all my love and Appreciation.

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ACKNOWLEDGEMENT

I would like to express my gratitude, respect and appreciation to my supervisor Dr. Basem Al-Abdullah, for proposing the problem, for his patience, guidance, help and encouragement through out this work, thanks for support all the way through.

Also I would like to give my best thanks to the examination committee: Prof. Mohammed A. Humeid, Prof. Ali Dabash and Dr. Malik Haddadin for their cooperation and valuable comments.

A very nice appreciation is extended to the manager Mr. Khaldoun Zauideh, and to Miss. Reema, Miss. Demah, Mr. Khalid, Mr. Zakariah and all the employees at the Quality Food Company (Unium) for their help and support.

Special thanks to my best friend Sawsan Al-Nsour, all my friends and the department employees; whom without I would not be able to achieve this work.

Finally I will never forget the support, guidance and help of whole my family, thanks for the encouragement.

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ABSTRACT

Influence of Mechanical and Hand Deboning on Meat Properties of Whole and Skinned Spent Layers

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Elevation in red meat price in Jordan; Which is the main component of meat products, is accompanied by efforts from the processors to reduce the cost of production. Consequently , the local processors have started to utilize the cheap spent layers as raw material in the comminuted and emulsified meat products.

Samples of chicken spent layers were prepared using four different deboning treatments, where treatment 1 represents the manual deboning of whole chickens, treatment 2: manual deboning of skinned chickens, treatment 3: mechanical deboning of whole chickens, and treatment 4: mechanical deboning of skinned chickens. The meat produced was packaged in polyethylene bags, frozen and stored at -18°C.

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Proximate analysis was done for protein, fat, ash and moisture, beside the determination of calcium content and pH. Functional properties including: emulsifying capacity (EC) and water holding capacity were measured.

It was found that treatments 2 and 4 that had the lowest fat content were of highest emulsifying capacity (153.8 ml oil/2.5g sample, 146 ml oil/2.5g). No significant differences were found in WHC values among the four treatments.

Determination of thiobarbituric acid (TBA) and peroxide value (P.V) were done to evaluate the oxidative rancidity of the fat in the samples. Results of TBA showed that the products of treatments 1 and 3 with the higher fat contents gave significantly higherTBA values, than treatments 2 and 4. Peroxide value results showed that the fat extracted from treatment 3 had the highest P.V.

It was found that some of the minerals analyzed like: Fe, Na, Al, K and Mg contents did not vary among the four products, while some others like Ca, Zn and Mn gave significantly higher values in treatments 3 and 4 when compared to that of treatments 1 and 2.

Measurement of bone content revealed a significantly higher bone content in mechanically deboned products (0.97%), than in hand deboned products(0.008%).

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Variability in pigment concentration was observed among the treatments; treatment 4 had the highest concentration with 2.590 mg/g, followed by treatments 2 and 3 with 2.417 mg/g and 2.413 mg/g, and the least pigment concentration was found in treatment 1 with 1.500mg/g.

Cholesterol content was found to be directly proportional to fat content; treatment 3 product gave the significantly highest cholesterol content with 122.55 mg/100g, and the least cholesterol level was found in treatment2 products with 43.92 mg/100g.

Sensory evaluation of the 4 products including aroma, color, texture and over all acceptance after 6 and 12 weeks of storage showed no significant differences in the aroma scores of the manually deboned meats after 12 weeks, while treatment 3 product showed a significant reduction in the aroma scores after 12 weeks of storage. Hand deboned meats had higher color scores than mechanically deboned meats.

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CHAPTER ONE

INTRODUCTION

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1. INTRODUCTION

The process of mechanical deboning of poultry and fish meat has received increased attention during the last 40 years (Froning ,1981). Field (1988), Babji *et al.*(1998) reported that the increasing price of meat and processed meat products has encouraged the food industry to evaluate the utilization of all protein sources, including by-products like mechanically deboned chicken meat (MDCM), chicken skin, spent hen meat and trimmings.

In Jordan, local meat processors are utilizing the low price spent hen layers as a raw material in the emulsified meat products like mortadella, luncheon, frankfurter, hotdogs and salami.

Hand deboning technique has some draw backs such as: low yield, and extensive labor cost, that encourages the processors to use meat deboning machines that give higher yield , need lower labor and give higher mechanically deboned meat ratio. As the demand for cut-up poultry increases there will be an associated increase in neck, back and frame supplies available to be processed into mechanically deboned poultry meat (MDPM). The primary use of mechanically deboned poultry meat has been considered as an important ingredient in emulsified- type products. (Dawson *et al.*,1988).

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The mechanical deboning that involves breaking of bone and its mixing with the meat and the skin leads to an expected changes in the chemical, physical, sensory and functional properties of the product (Barbut *et al.* 1985).

The objectives of this research are:

1. Study the effect of mechanical deboning on the composition of the resulted meat in comparison with hand deboning
2. Determine the effect of composition as replaced by mechanical deboning on the functional properties of meat.
3. Determine the effect of mechanical and hand deboning on the sensory properties and some quality attributes of the resulted meat.
4. Study the effect of various treatments on the meat storage quality properties.

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CHAPTER TWO

REVIEW OF LITERATURE

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2. REVIEW OF LITERATURE

Poultry is among the most popular food products in the world. Consumer demand for poultry is no doubt at least partly due to the acceptable or desirable flavors of poultry products (Baker and Bruce, 1995). The sale of poultry has increased rapidly with the result that this protein source is now a significant part of the nation's diet (USA) (Williams, 1986). Baker and Bruce (1995) reported that among the reasons for this increase are the relatively low growing costs, the rapid growth rate of poultry, the high nutritional value of the meat and the introduction of many new further processed products.

changes in life-style and consumption patterns have also helped to make poultry preferable source of meat. In this context, poultry has gained popularity because it is viewed as a good source of lean meat (Varnam and Sutherland, 1995).

2.1 Mechanical deboning process:

2.1.1 Definition and historical background:-

Mechanical deboning basically involves grinding of meat and bone together and forcing the meat through a fine screen or slotted surface, while bone particles left behind, become part of the waste residue as seen

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Figure (2-1) (Froning, 1981; Baker and Bruce, 1995). It was reported by Froning (1981) that further processing and mechanical deboning of poultry began in the late 1950's and early 1960's, and this mechanically debonded poultry meat supply became available to use in a variety of new products like: Frankfurthers, Salami, Bologna.

Froning (1981), Field (1988) found that the mechanical deboning process offers a method of harvesting meat from poultry that would otherwise be wasted, and in view of the world food shortage, this technique provides a means for helping to feed the world.

Since mechanically deboned meat is lower in price than other meat ingredient, so it is used in a wide variety of processed products (Field, 1988; Baker and Bruce,1995).

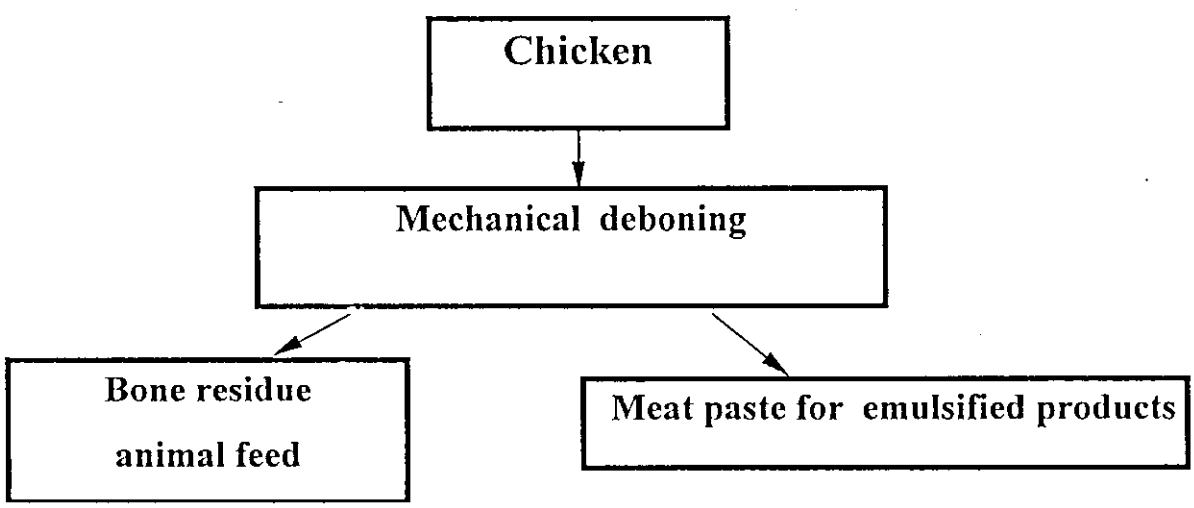

Figure (2-1): Deboning of poultry meat, (Froning, 1981)

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2.1.2 Types of mechanical deboners

Several types basically categorized into two different groups: one design forces the meat from the out-side to the inside of a perforated drum, leaving the bone residue on the outside of the drum, while the other design separates the meat from bone by forcing the meat from the inside to the outside of a perforated cylinder leaving the bone residue on the inside to be expelled out(Froning, 1981).

2.1.3 Nature of meat for deboning

It was reported by Baker and Bruce (1995) that broiler parts are commonly utilized for deboning process and whether dark or white meat selected will be determined by consumer preferance. For example in U.S.A breast meat is in great demand leaving a surplus of dark meat, wings are highly abundant, both legs and wings have poor meat yield (Froning, 1981).

2.2 Mechanically deboned meat (MDM)

2.2.1 Definition

Field (1988) defined MDM as a product resulting from the mechanical separation of meat from bone and this include recovering meat

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left on bones from handboning operation, from whole carcass or from parts of it.

There are other terms for MDM such as: mechanically separated meat (MSM) and mechanically recovered meat (MRM).

This term (MDM) adopted at the tenth (10^{th}) session of the Codex Committee on processed meat and poultry products in Copenhagen in 1978 and by the USDA in 1982. MDM has a paste like texture finely ground, finely chopped which limits the manner in which it can be used, as a result of the considerable cellular disruption the myofibrils are heavily fragmented (Schnell *et al* ., 1974; Froning, 1981 and Baker and Bruce, 1995). On the contrary poultry meat obtained by hand deboning process retains most of the characteristics of the whole bird (Baker and Bruce, 1995).

2.2.2 Composition

2.2.2.1 Bone content

Froning (1979), Filed (1988) reported that as a result of the grinding of meat and bone together then using fine screens, there will be some small bone particles still in meat, the inclusion of bone fragments in (MDPM) mechanically deboned poultry meat will not present any health hazard

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because of finess of residual and the bone content of MDM is limited to 1% (Froning, 1979; Froning, 1981).

When bone particles from hand deboned poultry meat and MDPM were isolated, the largest bone particles were found in the hand deboned poultry (average diameters 513 μm). While in MDPM (average diameter 233μm) so bone particles from MDM present no hazard (Froning, 1979).

Field (1988) stated that bone content of MDM can be estimated by the determination of Ca content; Ca makes up 37% of the bone ash in poultry. Upon comparing the bone content in both hand and mechanically deboned meat, Field and Riley (1974 a), Demos and Mandigo (1995) reported that MDM has higher ash and Ca content which indicated higher bone particles than in hand deboned meat.

2.2.2.2 Mineral content

In mechanical deboning and during the grinding and separating operations a certain amount of bone marrow and bone flour get into the meat, and as with hand deboning techniques may leave small amounts of powdered bone (Essary, 1979; Froning, 1981). So, accordingly it was considered important to determine the levels of different minerals present in comminuted meat. The main minerals checked for their levels

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in broilers are in Table (2-1) Ca, Fe, K, Na, Mg, Mn and Zn (Essary, 1979; Ang and Hamm, 1982).

Table (2-1): Comparison of minerals content of MDPM and HDPM. (Ange and Hamm, 1982).

Minerals / Treatments	K (mg/100g)	Na (mg/100g)	Ca (mg/100g)	Mg (mg/100g)	Zn (mg/100g)	Fe (mg/100g)	Mn (mg/100g)
Mechanical deboning	123-151	48-62	53-91	13-15	1.13-1.78	1.45-1.86	0.019-0.026
Hand deboning	97-147	35-60	14-34	10-13	1.04-1.83	0.86-1.14	0.015-0.019

2.2.2.3 Contribution of bone marrow

Filed (1988) summerized the contributions of bone marrow to the MDM which include:

1. The total lipid and fatty acid content
2. The color of the product
3. The relatively high pH
4. The protein quality.
5. The minerals.

Bone marrow is the major factor differentiating the mechanical deboning (MD) from hand deboning (HD), the differences enhance some functional properties as well as the nutritional value of meat (Essary, 1979; Field, 1988).

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2.2.2.4 Protein

Webb *et al.* (1976), Ang and Hamm (1982) found that during the process of deboning, a portion of the bone marrow constituents is incorporated into the meat product, and as any other component of meat protein content had been changed.

Mechanically deboned tissue has significant higher quantities of sarcoplasmic and non protein nitrogen than hand deboned tissue, which is due to the incorporation of more free amino acids and protein associated with the skin and possibly bone marrow by the mechanical deboner, while no significant difference was found between the level of myofibrillar protein for the two treatments (Webb *et al.* 1976). Field and Riley (1974 a), Field *et al.* (1974 b), Gillett *et al.* (1976), Webb *et al.* (1976) and Ang and Mamm (1982) found that MDM and HDM have similar percentage of protein content means no significant difference in level of protein between these 2 types of treatments.

Sattlerlee *et al.* (1971) studied the influence of skin content on composition of MDPM, and found that as the skin content increased in relation to muscle and bone content the protein content decreased, thus this meat has poor emulsifying characteristics. In skin, bone and connective tissue, collagen is the major protein component which is detrimental to

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emulsifying capacity (E.C) of meat (Satterlee *et al.*, 1971; Essary, 1979 and Ang, 1986).

2.2.2.5 Fat

Merck and Ball (1973) reported that upon mechanical deboning, there will be unknown quantities of bone marrow in the deboned meat. Because oxidative rancidity is believed to be the major cause of flavor deterioration, lipid composition of bone marrow could have a significant influence on the stability of finished products containing deboned meat (Merck and Ball, 1973; Ang, 1986). Thus, as a result of the bone marow incorporation into the deboned product variation in the fatty acid content , and higher % of cholesterol and phospholipids (PL) in MDM.

Merck and Ball (1973) found that the lipid content of chicken bone marrow was 46.5%; 98.4% of the total lipids, were neutral lipids with triglycrides (T.G) (the predominate lipid), while phospholipid fraction is 1.7% of total lipid on weight basis. The bone marrow T.G were slightly lower in linoleic acid than that of soft tissue samples, but higher in unsaturated fatty acids (USFA).

The fatty acid composition in bone marrow was found to be similar to that of hand-boned products (Froning, 1981; Field, 1988). Slight increase in the content of oleic acid in the final product, but no effect on

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the linoleic acid content upon the replacement of MDPM for HDPM was observed (Froning, 1981). In poultry, the phospholipids (PL) were more unsaturated than in red meat, and PL contained high levels of PUSFA (20-24C). The polyunsaturated bone marrow phospholipids could be susceptible to autoxidation, the heme pigments present in bone marrow may also accelerate the oxidation of PL (Merck and Ball, 1973; Froning 1981).

2.2. 2.6 Cholesterol

Bone marrow contains high cholesterol content of about 1.4% (wt/ wt) than does other broiler tissue (Froning, 1981). It was reported by Ang and Hamm (1982) that when comparing the cholesterol levels in hand and mechanically deboned broiler product, slightly higher levels were found in MD samples and these levels were higher than 70mg/100g, In hand deboned samples, the cholesterol level was 81mg/100g samples while MD samples have an average of 94.6mg/100g .

Kunsman *et al.* (1981), and Ang and Hamm (1982) explained that in hand deboned samples none of the cholesterol was from the spinal cord which contained 24.1 mg/cord, while in MD samples the cholesterol was from both the body fat and spinal cord, so the large variability here in

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cholesterol value can be related to the amount of marrow present. So cholesterol content of MDM depends upon:-

1. The amount of lean tissues left on the bone which are to be mechanically deboned.
2. The amount of marrow.
3. The amount of spinal cord.

2.2.3 Uses of MDM

Froning *et al.* (1971) reported that poultry meat in various forms is considered as important ingredients in emulsified products and MDPM has received increase interest in emulsified products since it is in a paste form with texture of finely grounded particles. The USDA has recently guaranteed approval for the addition of poultry meat as MDM into other meat products (Froning *et al.*, 1971; Kunsman *et al.*, 1981 and Field, 1988).

Processors have expressed interest in the possibility of incorporating MDPM into red meat frankfurters (Froning *et al.*, 1971; Froning and Johnson, 1973).

Marshall *et al.* (1977), Baker and Kline (1984) found that MDM appears to be ideally suited for incorporation into finely comminuted sausage products. Sometimes the high fat and high pigment content of

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MDM limited its use in light colored meat products (Froning, 1981; Baker and Kline, 1984 and Barbut *et al.,* 1985).

2.2.4 Flavor stability

The mechanical deboning process causes considerable cellular disruption, therefore it may speed up the development of rancidity, deterioration and oxidation (Froning, 1981).

Froning (1981) and Baker and Bruce (1995) reported the factors that determine the flavor stability of MDM:

1. Mechanical stress applied to the muscle during deboning (not significantly affect the TBA value).
2. Temperature of deboning drum (adverse effect).
3. Heme pigments in MDM, these various heme pigments act as catalysts in the autoxidation of lipids in meat.
4. Contact with the metal deboner and higher temperature may result in increased oxidation of both heme and lipid components.

Many researches have investigated the use of antioxidants to maintain desirable flavor since lipid rancidity is a major problem (Froning, 1981; Baker and Kline, 1984 and Barbut *et al.,* 1985). Immediate rapid freezing after deboning protects meat flavor and gives desirable attributes. (Field, 1988; Yang and Froning, 1992).

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2.2.5 Storage stability

The MD process has been found to affect storage stability in terms of rancid odors (Froning, 1981). Several studies have dealt with flavor changes in MDP during storage (Froning, 1981; Baker and Bruce, 1995). TBA number test was used as an evaluating test to flavor and aroma scores beside the organoliptic evaluation (Miller, 1994)

Froning and Johnson (1973) found that centrifugation to remove excess heme and lipid components improved the storage stability of MD fowl meat, while no observed advantage was by centrifugation on the storage stability of MD chicken meat. Jantawat and Dawson (1980 a) mentioned the factors involved in serious storage problems in MDM these include:-

1. Lipid incorporation from skin and bone resulted in lower protein and high fat contents.
2. Three fold increase in the total heme pigments in MDM when compared to hand deboned meat.

Jantwat and Dawson (1980 b), Baker and Kline (1984), Field (1988) and Yang and Froning (1992) reported that vaccum packaging to prevent oxygen penetration beside immediate rapid freezing of the product (MDM), certain washing treatments to reduce lipid and pigment

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concentration in meat. Using some antioxidants may help in the preservation and protection of MDM during storage.

2.3 Mechanical deboning and its effect on product properties

2.3.1 Functional properties

2.3.1.1 Emulsifying capacity (EC)

Since most of MDM is utilized in emulsified products the EC is an important characteristic to these products (Froning, 1981; Field, 1988). Swift *et al.* (1961), Ivery *et al.* (1970) and Kato *et al.* (1985) have defined the EC as the amount (volume) of oil that can be emulsified by the meat extract prior to inversion or emulsion collapse.

Swift *et al.* (1961), Froning (1973) measured the EC as ml oil/2.5g meat. Swift *et al.* (1961), Acton and Saffle (1972), Galuzzo and Regenstein (1978), Wang and Zayas (1992) and Zorba *et al.* (1993) summerized the factors affecting emulsifying properties of protein:

1. Protein concentration
2. Medium pH
3. Temperature of oil
4. Mechanical force (comminuting)
5. Rate of oil addition during emulsification.

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While studying the EC of some meat proteins actin, myosin, sacroplasmic and actomyosin, its functionality is not entirely clear, the presence of salt greatly depressed the effectiveness of actin while myosin intermediatly (Swift *et al.,* 1961). Without exception the proteins studied exhibited a great EC per unit of protein as the protein concentration was reduced (Swift *et al.,* 1961; Ivey *et al.,* 1970 and Gillett *et al.,* 1977).

Tasi *et al.* (1972) ranked proteins from greatest to least EC: actin in absence of salt, myosin, actomyosin and sarcoplasmic. Swift *et al.* (1961) concluded that proteins in meat products function at much less than their EC value since maximum EC needs thorough disintegration and dispersion of tissue in a relatively dilute system. The pH of the medium indirectly affects the EC of protein by influencing protein solubility (Wang and Zayas, 1992). The higher pH of MDM increases extractability of the muscle proteins resulting is an improved emulsifying power of the meat (Anderson and Gillett, 1974; Field, 1988).

Ideal oil temperature to form emulsion was generally around 11-18°C (Swift *et al.,* 1961; Galluzzo and Regenstein, 1978 and Zorba *et al.,* 1993). Swift *et al.* (1961), Ivey *et al.* (1970) and Galluzzo and Regenstein (1978) reported that high blending rate produce lower E.C value, that the blender speed affect inversly the amount of oil emulsified by the meat

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extract. So a sufficiently mixing rate with rapid addition of fat employs emulsifying capacity most effectively.

Most of researchers found that a rate of 0.8-1ml/sec as a rate of oil addition is sufficient and proper to give effective E.C (Swift *et al.*, 1961; Guzzalo and Regenstein, 1978).

Addition of salt leads to salt-protein interaction because salt may unfold protein that increases the solubility of myofibrillar proteins, and extends the surface area of protein films. Thus the addition of high salt concentration will increase protein concentration thus reduce E.C (as ml oil/100mg protein) (Gillett *et al.*, 1977; Gaska and Regenstein, 1982). Froning and Johnson (1973) and Field (1988) studied the influence of skin content of MDPM on E.C; they found that as the level of skin content prior to deboning was high, there was a significant decrease in the E.C because there was an increase in fat content of MDPM.

Frozen meat had higher E.C value than fresh meat at all salt and phosphate levels, since upon freezing partial denaturation of the myofibrilar meat proteins which would lead to a slightly increase in protein solubility, beside an increase in pH value (Gillett *et al.*, 1977; Zorba *et al.* 1993).

Many workers have demonstrated with light microscopy that the structure of meat emulsions is similar to classical emulsions to the extent

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of fat globules being surrounded by a limiting membrane. The fat was distributed as globules of different sizes ranging from 0.1-50 μ and was encapsulated by a matrix of protein, the salt soluble proteins myosin and actomyosin concentrate at the fat globule surface forming a stabilizing membrane (Swift *et al.,* 1961; Tasi *et al.,* 1972).

2.3.1.2 Water holding capacity (WHC):

Meat including poultry contains about 70% water in the native state, much of this water is not tightly bound and known as "free water" (Baker and Bruce, 1995).

Water holding capacity of muscle foods has been utilized as an index of palatability, microbial quality and manufacturing potential (Dagbjartsson and Solberg, 1972). Field (1988) reported that water holding capacity is very important in the formulation, processing, cooking and freezing of meat because it relates to weight loss and quality of the finished product.

Jauregui *et al.* (1981) and honikel and Hamm (1994) reported some other names of WHC these are:-

Expressible moisture (EM), water binding potential (WBP) and free drip.

Field (1988) found that the factors affecting WHC are:-

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1. pH: mechanically deboned meat have higher pH than hand deboned meat, the high pH value is due to the incorporation of red marrow which has a pH in a range of 6.8-7.4; so the MDM has improved WHC.
2. Presence of Fe, Cu, Ca, Mg from bone powder: these minerals are found in higher concentration in marrow than in muscle and exert a negative correlation.
3. Collagen: which is the major connective tissue protein; collagen range of most MDM is between 3-4% of fresh tissue weight. These levels are much less than the 15% level that have been considered detrimental to the functional properties of meat.
4. Skin: it was found that skin did not change the WHC of both skin or skin-less mechanically deboned meat.
5. Cooking: upon cooking the MDM protein denaturates leading to reduction in the WHC when compared to raw MDM.
6. Freezing: upon freezing, MDM will have more drip over the unfrozen MDM so WHC will be reduced.

In conclusion WHC of MDM is equal to or better than hand deboned meat.

2.3.2 Lipid oxidation

Rancidity is one of the major causes of loss of quality in any food containing fat (Baker and Bruce, 1995). Jantawat and Dawson (1980 a),

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Barbut *et al.* (1985), Johns *et al.* (1989), Rhee *et al.* (1996) and Fernandez *et al.* (1997) reported that MDM is highly susceptible to oxidative deterioration. This is related to the release of heme, oxidative enzymes and the incorporation of oxygen into the product during the machine deboning process that promotes the autoxidation of PUSFA located in the phospholipids of poultry tissue.

According to Ahn *et al.* (1992) and Kanner (1994) factors affecting MDM lipid oxidation are:-

1. Fat content: The fat content of MD products increased due to the stripping of fat from bone marrow and/ or skin during deboning process (Janky and Froning, 1975; Jantawat and Dawson, 1980 a).
2. Poly unsaturated fatty acids content PUSFA: The more the fat the more is the unsaturated fatty acid originating in phospholipids which has been attributed to their high content of PUSFA (Melton, 1983).
3. Metals such as Fe and Cu: That work as catalysts. Iron can be found in pigments, ferritin, enzymes and as free iron (Janky and Froning, 1975; Ahn *et al.,* 1992).
4. Heme catalysts: Janky and Froning (1975), Froning (1981) and Kanner (1994) found that the heme portion of the myoglobin molecules as well as other heme pigment may act as catalysts in autoxidation of lipid in meat.

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5. Enzymes like lipoxygenase or cycloxygenase but only if the enzymes are activated by preformed peroxides and fatty acids are in free form (Kanner, 1994).

Lipids oxidation measurement has been widely done using Thiobarbituric acid method (TBA). TBA has a high correlation with sensory evaluation (Barbut *et al.,* 1985; Whang and Peng, 1987; Rhee *et al.,* 1996 and Fernandez *et al.,* 1997). Another method to evaluate lipid oxidation is to monitor the changes in fatty acid profile during storage, mainly the arachidonic acid (20:4) in phospholipid fraction which decreases appreciably during storage if oxidation occurred (Whang and Peng, 1987).

The addition of MDM to red meat resulted in decreased product shelf-life as measured by sensory evaluations and TBA (Barbut *et al.* 1985). So the increased utilization of MDM in processed meat products necessitates the following:

a. The addition of antioxidants such as butylated hydroxy anisole (BHA), butylated hydroxy toulene BHT and sodium tripolyphosphate (Froning, 198l; Barbut *et al.,* 1985 and Baker and Bruce, 1995).
b. Metal chelating agents (Froning, 1981; Ahn *et al.,* 1992).
c. Impermeable to oxygen packaging material and vaccum packages (Ahn *et al.,* 1992; Baker and Bruce, 1995).

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2.3.3 Meat color

The color of fresh meat is one of the most important meat quality characteristics taken into account by consumers; as they tend to select the normal pink red color and reject pale, soft oxidative and dry, firm dark meat (Rickansrud and Henrickson, 1967; Garrdio *et al.,* 1994 and Kanner, 1994).

The mechanical deboning process release substantial quantities of hemoglobin from bone marrow which is subsequently extruded with MDPM. The myoglobin content was not influenced by the MD process (Froning, 1981). The pigments responsible for the color of MDPM are hemoglobin and myoglobin (Froning, 1981; Hernandez *et al.,* 1986).

Meat color determination is done by salting-out procedure (Rickansrud and Henrickson, 1967). Several other methods have been described to measure total pigment concentration in muscle by using extraction into solution and spectrophotometric measurement of one or several derivatives (Rickansrud and Henrickson, 1967; Garrido *et al.,* 1994). The currently available methods have drawbacks including the use of very toxic substances such as cyanides, specialized equipment, extremely long routine analysis time and low sensitivity (Garrido *et al.,* 1994).

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Heme pigments in MDM are known to interact with intramuscular fat causing flavor problems (Janky and Froning, 1975; Froning, 1981). In mechanical deboning the high pressure conditions may creat significant increases in temperature of separated meat and the contact with the metal of the deboner may all result in acceleration the oxidation of both heme and lipid components (Froning, 1981). Myoglobin state is probably affected by mechanical deboning thereby influencing color changes (Froning, 1981).

When oxygen is mixed thoroughly with meat, myoglobin and hemoglobin are converted to the oxy-form which become a problem during storage because they can be oxidized and produce brown, green and gray colors (Field, 1988; Madhavi and Carpenter, 1993).

Metal ions from the mechanical deboner or anions from Ca and P in bone were involved in heme oxidation as catalysts (Field, 1988). In general the MDPM has a brighter red color than their hand-boned counter parts, but is more prone to oxidation, To overcome this problem rapid freezing immediately after mechanical deboning have proven successful (Field, 1988). When skin left on poultry parts to be mechanically deboned, fat from skin dilute the heme pigments producing lighter color, and also fat from bone marrow acts to dilute the color (Froning, 1981; Field, 1988).

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Using the MDM with its bright red color is considered desirable in many processed meat products, but this color would be a problem if this MDM is needed to be added to products of low pigment concentration (Field, 1988), so modifying the color characteristics of MDPM can be done.

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CHAPTER THREE

MATERIALS AND METHODS

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3. MATERIALS AND METHODS

3.1 Preparation of Chicken Meat Samples

Spent layers chickens (Leg horn breed) for this study were obtained from a local company where the chickens were slaughtered, dressed and chilled. Chickens have an average weight of 800-1000g and were 70-80 weeks old. Chickens were divided into 4 groups, in order to be subjected to 4 deboning treatments in local meat industry.

3.2 Deboning of Chicken meat samples

The four groups were treated as follow:

Treatment One: included the manual deboning of whole chickens, where the resulted meat was as pieces and was divided in portions of 0.5 Kg, packaged in polyethylene bags, rapidly frozen and stored at –18°C.

Treatment Two: the manual deboning was carried out on skinned chicken carcasses, while packaging, freezing and storage was carried out as described in treatment one.

Treatment Three: included the mechanical deboning of whole chicken using deboning machine (Stork Protecon Langen), the resulted pasty product was packaged in poly ethylene bags and stored as in treatments one and two.

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Treatment Four: the mechanical deboning process was carried out for the skinned chicken carcasses, and the resulted product was treated as in the previous treatments.

3.2.1 Mechanical deboning process:

The chicken deboning machine (Figure 3-1) consists of hopper, feed screw, sieve chamber, front ending for the recovered bones.

From the loaded hopper, the feed screw conveys the input material (4°C) through the pre-sizer and vane pump into a separating chamber where the meat was subjected to pressing forces, meat is then extruded through the sieve with temperature around 6-8°C. The auger screw inside the filler discharges the bone residue through the front end of the deboner and simultaneously clears the sieve (Figure 3-1). One great advantage of this system is that pressure level can be adjusted during processing, this means that constant control over yields is possible even when in full production.

For all the treatments the yield waste and efficiency were calculated.

3.2.2 Sample preparation

Samples representing the four treatments were taken, and allowed to thaw at room temperature, the mechanically deboned meat products were mixed thoroughly to have a homogenous samples, on the other hand the manually deboned meat products were chopped using meat mincer (Hobart) with grinding plate (of 2 mm opening size), then mixed

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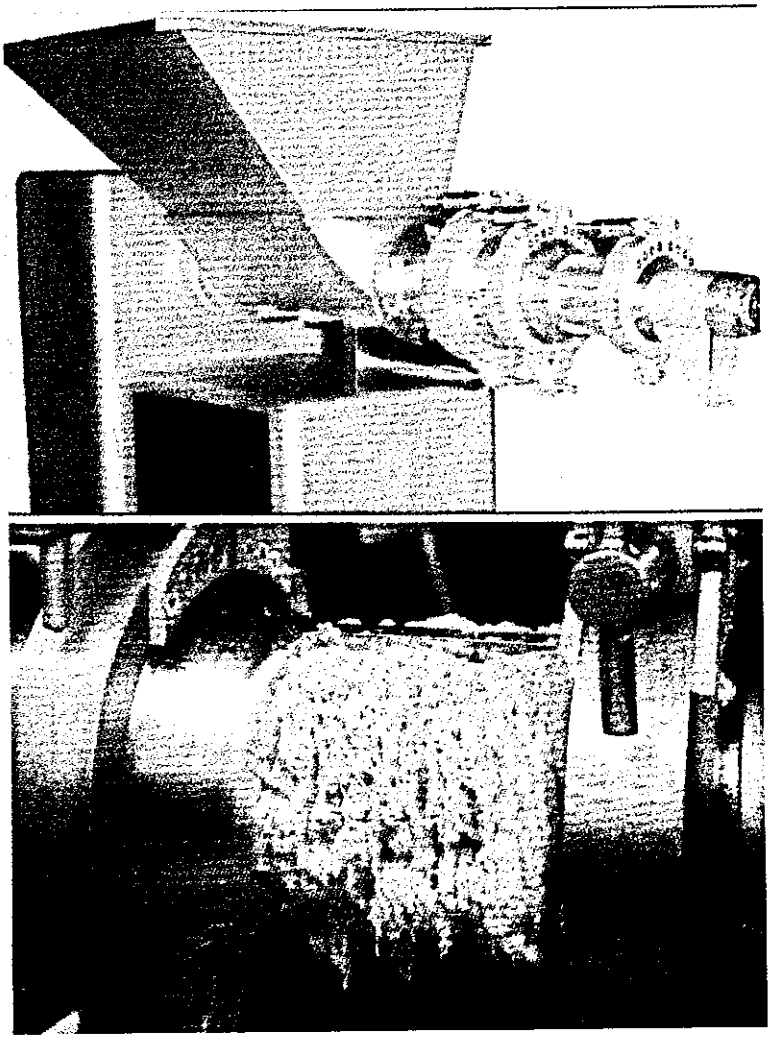

Figure (3-1): Chicken deboning machine (Strok Protecon Langen B.V.)

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thoroughly to be homogenous, by this the samples are ready to be used for proximate analysis. This general procedure was carried out before all the chemical tests and sensory evaluation.

3.3 Proximate Analysis

Samples representing the four treatments were analyzed for moisture using oven drying method according to Kirk and Sawyer (1991).

Fat, protein, moisture and collagen contents determinations were done using Infratec meat analyser (Tecator 1265) according to Berg and Kolar, 1991.

Ashing determination was carried out according to the method described in AOAC (1995) method number 920. 153.

3.4 pH value

The hydrogen ion concentration was determined as described by Kirk and Sawyer (1991); ten grams meat sample were blended with 100ml distilled water using stomacher (Model AES, Laboratory) and the pH value was measured using pH meter (Model WPA, Cambridge).

3.5 Functional Properties

Water holding capacity and emulsifying capacity were determined for the meat samples.

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3.5.1 Water Holding Capacity (WHC)

WHC was evaluated as described by Honikel and Hamm (1994). The method is based on subjecting the meat to centrifugal forces to expell liquid. A low speed centrifugation method was used that; in 50 ml centrifugation tubes (2g) an absorbant material (sodium sulfate) was put and then 10 g of meat were weighed accurately, the tubes were placed in fixed rotort (Céntaur 2, MSE) and centrifuged at 4000 rpm for 20 minutes. Meat samples were removed directly by forceps from the tubes, dried gently using absorbant paper and then weighed. Weight loss was calculated, WHC of samples was calculated according to the following equation:

$$\text{WHC (g } H_2O\text{/g protein)} = \frac{\text{Water in the sample (g)- Water lost from the sample (g)}}{\text{Protein in sample (g)}}$$

3.5.2 Emulsifying Capacity (EC)

The procedure used for EC is a modification of the method used by Swift *et al.* (1961). The basic method used was as follows:

Fifty grams of the meat sample were placed in a blender jar with 200 ml of 1M NaCl (0-5°C), the mixture was comminuted for 2 minutes in blender (Toshiba MX – 460 G), Twelve and half grams of the resultant slurry were placed in a 500 ml beaker and 37.5 ml of 1M NaCl (0-5°C) was added, the mixture was mixed for 20 seconds using an ultra speed mixer

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(Ultra- Turrax T 25), then fifty millileters corn oil were added from graduated cylinder and high-speed mixing cutting was begun at 13000 rpm, corn oil was added at a rate of about 1 ml/ second using a pipette. Emulsion formed, persisted and finally collapsed, the transition being marked by a gradual increase followed by a sudden decrease in viscosity. The addition of oil was terminated when the emulsion breaks, the electrical conductivity of the emulsion was monitored during the forming and collapse of the emulsion using conductivity meter (4310 JENWAY), and the EC was expressed in terms of ml oil/ 2.5g meat.

3.6 Rancidity Evaluation

3.6.1 Peroxide value (P.V)

The oxidative rancidity of the extracted lipid from meat samples was evaluated by P.V according to Hutchinson (1995). Lipid extraction from the meat samples was done using a centrifuge, this was done by mixing the ground meat samples with water then subjecting the mixture to centrifugation, where three layers were obtained, layer of meat tissue, and layer of pigment turbid liquid and an upper clear oil layer, which was removed carefully by frequent decating. P.V (milliequivalent O_2/ Kg oil sample) calculated according to the following equation:

$$\mathbf{P.V} = \frac{(V_1 - V_2) \times N \times 1000}{\text{Sample weight (g)}}$$

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Where:

V_1= ml of $Na_2S_2O_3$ consumed by the sample.

V_2= ml of $Na_2S_2O_3$ consumed by the blank.

N = Normality of $Na_2S_2O_3$ solution = 0.1 N

3.6.2 Thiobarbituric acid number (TBA)

A spectrophotometric test was carried out for the 4 treatments samples as described by Johns *et al.* (1989), Faustman *et al.* (1992).

TBA number was expressed as mg malonaldehyde / Kg sample.

TBA no.= 7.8 × D

Where D = Absorbance of sample at 532 nm.

3.7 Minerals Determination

The determination of minerals concentration was carried out using Inductively Coupled Plasma Emisson Spectrometer (I.C.P 2000 BAIRD) was done as the following:

Mineralization of sample: Five grams sample was weighed and transfered into a beaker, 10 ml of 50% (V/V) HNO_3 was added and mixed with the sample. The mixture was heated to 95°C and allowed to reflux 10-15 minutes, cooled, and 5 ml concentrated HNO_3 was added and the solution was let to reflux 30 minutes at 95°C, the solution was evaporated to about 5ml, after cooling, 2ml deionized water and 3ml of 30% H_2O_2 (V/V) were

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added then allowed to heat slowly, other 7 ml of 30% H_2O_2 in1 ml portions was added, 5 ml concentrated HCl and 10 ml deionized water were added, the solution was then let to reflux for 15 minutes.

Spectrophotometric measurement: the solution was diluted to 100 ml with water, then nebulized into radio-frequency I.C.P and intensities were measured by photo multiplier tubes.

3.7.1 Bone Content

Calcium content values of samples were used to determine the bone content. Since Calcium content represent 24-26% of bone content of chicken, bone content was determined according to (Satterlee *et al.*, 1971; AOAC, 1995) using the following equation for calculation:

$$\textbf{\% bone content} = (\textbf{Ca \%} - 0.015) \times 4.55$$

Where:

0.015: Correction of natural Calcium in poultry muscle tissue.

4.55: Calcium to bone conversion factor for mature chickens.

3.8 Total Meat Pigment Determination

The color of fresh meat is one of the most important quality characteristics taken into account by consumers. So several methods have been described to measure the total pigment concentration in meat. This method is based on phase partitioning in Triton X-100 and oxidation with $NaNO_2$, as described by Garrido *et al.* (1994). In this test 3 g meat sample

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was homogenized in 30 ml of 40 mM phosphate buffer (pH = 6.5) for 20 seconds using homogenizer (Ultra-Turrax T 25), the resultant homogenate was filtered using filter paper Whatman (no.1), 4 ml of the filtrate were then transfered into 10 ml test tube and 1.4 ml of Triton X-100 (100g / L) and 0.1 ml of 65 mM $NaNO_2$ were added, after 60 minutes and at 22°C the absorbance at 730 and 409 nm was measured.

Pigment concentration (mg/g) = [A_{409} – (A_{730} × 2.68)] × 3.249

Where:

A_{409}= Absorbance at 409nm

A_{730} = Absorbance at 730 nm

3.9 Cholesterol Content Determination

This test includes 2 steps:

3.9.1 Cholesterol extraction

This step was carried out according to Boehringer (1997). Two grams meat sample were weighed in 50 ml roundbottom flask, then 10 ml of freshly prepared methanolic KOH solution (1 mol/L) were added and heated under reflux condenser (20 minutes), the cooled content transfered into 25ml volumetric flask by piptte, then flask was rinsed with iso-propanol, and 1ml of 8 M HCl was added, and the volume was made up with isopropanol to the mark. The flask was then immersed in an ice-bath

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for 10 minutes, to allow free fatty acid precipitation, after filtration through a slow- filter paper, the resultant filtrate was used for the assay step.

3.9.2 Cholesterol determination

According to Trinder (1969), cholesterol determination was done after enzymatic hydrolysis and oxidation. Where the colorimetric indicator is chinonimine which is generated from 4-Amino- antipyrine and phenol by hydrogen peroxide under the catalytic action of peroxidase.

$$\text{Cholesterol ester} + H_2O \xrightarrow{\text{Cholesterol estrease}} \text{Cholesterol} + \text{Fattyacids}$$

$$\text{Cholesterol} + O_2 \xrightarrow{\text{Cholesterols oxidase}} \text{Choesterol-3-one} + H_2O_2$$

$$2H_2O_2 + \text{4-Amino antipyrine} + \text{phenol} \xrightarrow{\text{Peroxidase}} \text{Chinonimine} + 4H_2O$$

The intensity of the colored indicator was determined spectrophotometrically at 500 nm wavelength (Trinder, 1969). 0.01 ml of sample solution was pipetted into plastic tubes (in duplicates); 1ml of the kit reagent solution was added and then mixed thoroughly and incubated at 20°C for 10 minutes,. Blank duplicates which contain 1ml reagent only were treated similarly. Spectrophotometer (Perkin-Elmer, Cleman Instruments Division 55-215) was set zero on the blank at 500 nm absorbance.

The cholesterol content (c) was calculated as Follows:

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$$C(\text{mg/dL}) = \frac{A\ (\text{sample})}{A\ (\text{standard})} \times 100$$

Where:

A (sample) = Sample absorbance

A (standard) = Standard absorbance

The standard was cholesterol FS (200mg/dl)

While cholesterol concentration per 100g was calculated according to the following equation:

Cholesterol concentration (g / 100g) =

$$\frac{\text{C cholesterol (g/L sample solution)} \times 100}{\text{weight of sample (g/L sample solution)}}$$

3.10 Sensory Evaluation

The sensory evaluation of raw samples of the 4 treatments was carried out by 25 panelists selected from the teaching staff, graduates and technicians of the Department of Nutrition and Food Technology/ University of Jordan. The panilists were requested to evaluate color, aroma, texture and overall acceptance of the product using 9-points hedonic scale method (see Appendix 1). The words "Like extremely" and "dislike extremely" were set at opposite ends of scale with 9 indicating "like extremely" and 1 indicating "dislike extremely".

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3. 11 Statistical Analysis

The results were analyzed statistically with SAS statistical package. Analysis of variance for complete randomized- split plot design with Duncan's Multiple Range test and LSD test were performed to determine any significant differences between means of each treatment.

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CHAPTER FOUR

RESULTS

AND

DISCUSSION

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4. RESULTS AND DISSCUSION

4.1 Efficiency of the different deboning treatments

Table (4-1) shows the yield, waste and efficiency of the four deboning methods, it is clear that the mechanical deboning gave the highest yield and efficiency, where treatment 3 gave 78% efficiency, while treatment 4 gave 74% efficiency. In the case of hand deboning as in treatments 1 and 2 the yield and efficiency are clearly lower than those in treatments 3 and 4, treatment 1 gave 47% efficiency, while treatment 2 gave lower yield reaches to 15 kg with also low efficiency 37% and this was due to the removal of skin.

Table (4-1): Yield , waste and efficiency of the four deboning treatments.

Treatment	Chicken weight(Kg)	Yield (Kg)	Waste (Kg)*	Efficiency (%)
1	34	16	18	47
2	41	15	26	37
3	23	18	5	78
4	27.15	20	7.15	74

* In case of treatments 1 and 3; the waste is bone only, while in treatments 2 and 4; the waste is bone and skin.

Note: treatments:
1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

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4.2 Proximate composition, collagen and pH values of the meat in the different treatments

Table (4-2) shows the proximate composition, collagen, and pH of meat obtained from four deboning treatments of spent hen (layers).

Table(4-2): Mean values for proximate composition, collagen and pH of hand mechanically deboned chicken (spent layers) meat.

Treatments	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Collagen (%)	pH
1	69.70±0.0^{b}	20.85±0.92^{b}	8.90±1.27^{a}	0.98±0.0^{c}	1.60±0.14^{b}	6.33±0.0^{b}
2	74.25±0.35^{a}	22.65±0.07^{a}	2.75±0.35^{b}	1.10±0.028^{b}	0.85±0.21^{c}	6.32±0.014^{b}
3	69.85±0.21^{b}	20.45±0.63^{b}	9.15±0.21^{a}	1.25±0.014^{a}	3.45±0.07^{a}	6.48±0.014^{a}
4	70.95±1.20^{b}	20.35±0.21^{b}	7.55±0.07^{a}	1.32±0.028^{a}	3.00±0.0^{a}	6.44±0.016^{a}

* Each value is a mean of 2 readings.
* Means with the same letter in any given column are not significantly different at the 5% level of probability.
* Values are calculated on wet weight basis.
* Treatments:

1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

4.2.1 Proximate composition

4.2.1.1 Moisture content

Table (4-2) shows that meat obtained from the treatments 1,2,3 and 4 contained 69.70%, 74.25%, 69.85% and 70.95% moisture content respectively on wet weight basis, from the table the percentage moisture of treatment 2 was significantly different from that of other treatments due to skin removal, due to lowering the fat and increasing the moisture content of

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the meat. In treatment 4 the moisture content may be high but not significantly different from treatments 1 and 3. The difference in moisture content was attributed to the exposure of released bone marrow fat (as in treatments 3 and 4) which was highly concentrated as associated with the skin and bone marrow; that mechanical deboning near the skin surface (as in treatment 3) was believed to be sufficient to remove more of the fatty tissue attached to the skin than accomplished by hand skinning (as in treatment 1).

The presence of skin as in treatments 1 and 3 leads to an increase in the fat content which in turn lowered the moisture content. So, the variation in moisture content was due to the presence of skin and fat which lower the moisture content and due to the incorporation of bone marrow fat which elevates the fat content in the mechanically deboned samples, and these results were in agreement with those found by (Demos and Mandigo, 1995).

4.2.1.2 Protein content

As it appears from Table (4-2), meat in treatment 2 showed a significantly higher protein content than other treatments. In treatment 2 and due to the removal of skin beside the low fat content and no incorporation of bone marrow the protein content was high, while in treatment 3 and 4 and as described previously the mechanical deboning lead to the release of free amino acids and protein associated with the skin

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and possibly bone marrow by the mechanical deboner. High amount of intracellular materials may have been released due to the muscle tissue being more completely macerated, but here the release of fat from skin and / or bone marrow worked to elevate the amount of fat and decrease the amount of protein.

4.2.1.3 Fat content

Moisture and protein contents of treatment 2 (Table 4-2) showed the significantly different values, this treatment gave significantly lowest fat content reached to 2.75% and this could be attributed to the absence of skin beside that no bone marrow fat was incorporated, while in treatment 1 and was due to the presence of skin; with a fat content was significantly higher (8.90%).

Mechanical deboning in treatments 3 and 4, the high fat content in the bone marrow incorporated in the meat, increased the level of lipids in the mechanically deboned samples, where lipid content of chicken bone marrow was approximately 46.5%. In these treatments skin content did not play a major role in the determination of fat content; that in treatment 3 fat content was 9.15% which is higher but not significantly than its content in treatment 4 which was 7.55% inspite of the presence of skin in treatment 3 and its absence in treatment 4, so it is clear that the incorporation of bone marrow fat played the major role in increasing the fat content when we compare treatments 2 and 4.

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4.2.1.4 Ash content

As can be seen from Table (4-2) mechanical deboning resulted in meat of a significantly higher ash content, the samples in treatment 3 and 4 had1.25% and 1.32% compared to 0.98% and 1.10% in treatments 1 and 2, the high ash values were a result of bone particles incorporated into the meat. Ash content may be considered as an indicator of bone content. The presence of skin worked to lower the level of ash content as in treatment 1 when compared to treatment 2; treatment 1 may have the same amount of ash but due to the presence of skin, the ash level was lower than that in treatment 2.

4.2.2 Collagen content

Table (4-2) shows significantly high values of collagen content in meat from the mechanically deboned treatments (3 and 4), the collagen is originated not only in skin but also as a major protein component in bone. The collagen content of the mechanically deboned samples was influenced by the presence of bone particles due to the breaking of bones to finely particles which may not pass out with wastes, and this as in treatment 4 where the collagen content was 3.00%, but in treatment 3 beside the collagen which came from bone protein, some collagen came from the skin so the collagen content was 3.45% . When the skin was passed through the deboner, the obtained product had low collagen content when compared to unprocessed skin and this could be attributed to the rest of collagen being

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extruded with the bone residue. But in treatments 1 and 2 and due to the absence of bone, skin played the major role in determining the collagen content; thus treatment 1 had a collagen content of 1.60 % which is significantly higher than that in treatment 2 (0.85%).

4.2.3 pH value

The pH values of samples from treatments 3 and 4 were 6.48 and 6.44 significantly higher than those of treatments 1 and 2 as in Table (4-2). This is related to the incorporation of bone marrow in the meat which has higher pH, the bones ground prior to lean retrieval showed a significant increase in pH values of these treatments, while those hand deboning treatments showed pH values 6.33 and 6.32 for treatments 1 and 2 respectively, which are significantly lower than those of treatments 3 and 4.

The ground bones lead to the release of minerals like Ca, Mg, K and Na and this leads to increasing the pH value in treatments 3 and 4 (Zorba *et al.*, 1993).

4.3 Functional properties

4.3.1 Emulsifying capacity (EC)

Table (4-3) shows significantly high EC value of treatment 4 which was 153.8 ml oil /2.5g followed by treatment 2 where it's EC was 146 ml oil /2.5g followed by treatment 3 where it's EC of 137.7 ml oil /2.5g , while the least EC value was in treatment 1 (127 ml oil / 2.5g).

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In mechanical deboning (as in treatment 4) and due to the incorporation of bone marrow protein, free amino acids and sacroplasmic protein content, was increased. The increase in pH value was due to the higher bone marrow pH value; the higher pH would lead to increase of protein solubility which is the limiting factor in improving the functional properties of meat. While in treatment 3 the EC value was significantly lower due to the presence of skin and its content of collagen which is considered detrimental to EC. In hand deboning treatments (treatment 2) significantly higher protein values were found. The relative increase in insoluble protein concentration is one of the major factors that affect the EC inversely; and in contrast to the relative increase of protein solubility which can be enhanced upon increasing the pH as shown in Figure (4-1). The hand deboning treatments gave products with significantly lower pH, and although their protein content was higher, their EC and functionality was lower.

The effect of insoluble protein concentration could be explained by the fact that its increase caused thicker layers of protein formation on the fat droplets, thus consuming more protein per drop, which may reduce the total surface area of oil that could be emulsified (Swift *et al.*, 1961). This phenomenon can be confirmed by the denaturation principle whereby the molecular orientation of the protein at the surface of the oil droplet becomes denatured when sufficient dilution was made to increase the EC

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when the emulsifying agent concentration (protein) is decreased a greater degree of unfolding of the protein helix occurred which allowed for a higher amount of molecular orientation to take place, this molecular orientation on the oil droplet surface gave greater stability to the more dilute system (Ivey *et al.*, 1970).

Table (4-3): means and standard deviations of EC values of different hand and mechanically deboned samples:

Treatment / Variable	1 $\bar{X} \pm$ S.D	2 $\bar{X} \pm$ S.D	3 $\bar{X} \pm$ S.D	4 $\bar{X} \pm$ S.D
EC [(a)]	127.0±13.2[d]	146.0±10.77[b]	137.7±2.5[c]	153.8±8.23[a]
Proteins(%)	20.85±0.92[b]	22.65 ±0.07[a]	20.45±0.63[b]	20.35±0.21[b]
pH	6.33±0.0[b]	6.32±0.014[b]	6.48±0.014[a]	6.44±0.016[a]

(a) EC as ml oil/2.5 g sample
* Each value is a mean of 6 readings
* Means with same letter in any raw are not significantly different at ($P \leq 0.05$).
* Treatments:
1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

As it is clear in Table (4-4) the meat from mechanical deboning treatments showed a decreasing trend in EC values during storage, the decrease was clear from the first month to the second month, while showing somehow stabilizing state in the third month; which means that mechanical deboning products showed their superior EC during the first

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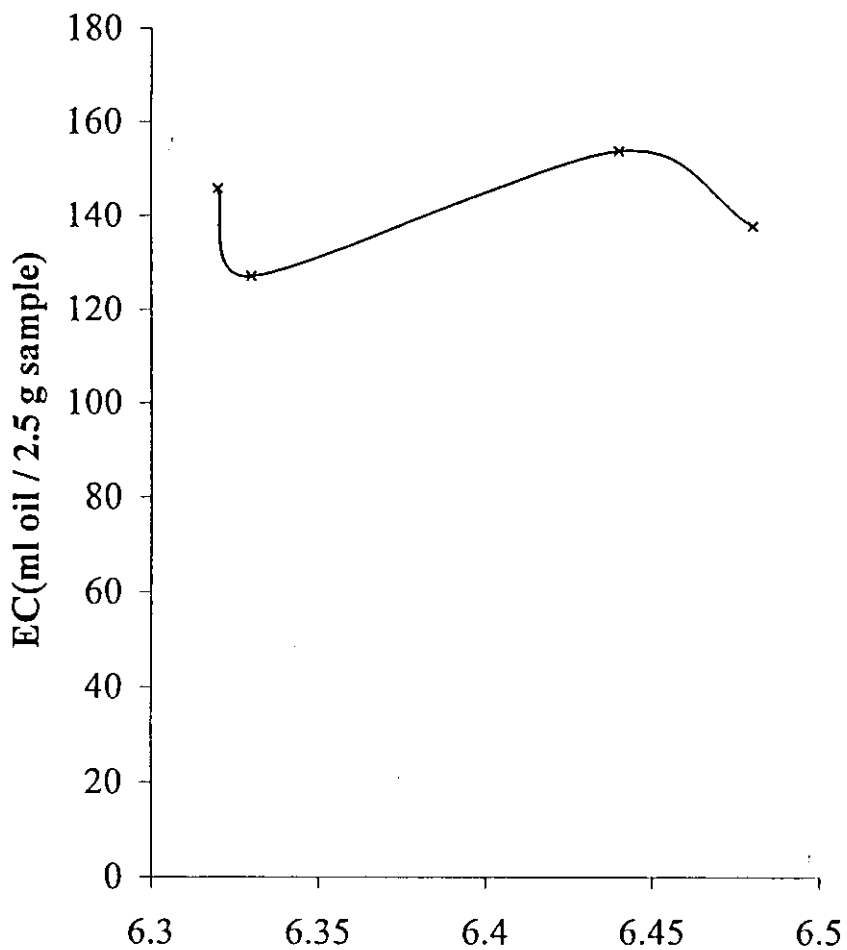

Figure (4-1): Emulsifying Capacity - pH Relationship for the Different Deboning Treatments

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of soluble protein which consequently reduce its emulsifying quality. The the hand deboned products however showed a clear improvement in their EC with time as shown in Figure (4-2), and this could be due to the absence of mechanical damage of the meat structure, which in turn kept the native state of protein intact. Despite the increase in the EC values of hand deboned products was at the same level at which the EC values decreased in the mechanically deboned products.

Table (4-4): Effect of storage time on the EC values of the 4 deboning treatments

Treatments	E.C. values (ml oil/2.5g sample) after		
	1 month	2months	3 months
1	110.0[b]	136.0[a]	135.0[a]
2	132.5[b]	152.5[a]	153.0[a]
3	140.5[a]	136.5[a]	136.0[a]
4	164.0[a]	147.5[b]	150.0[b]

* Each value is a mean of 2 readings.

* Means with the same letter at any given row are not significantly different ($P \leq 0.05$) using LSD test.

* Treatments:
1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

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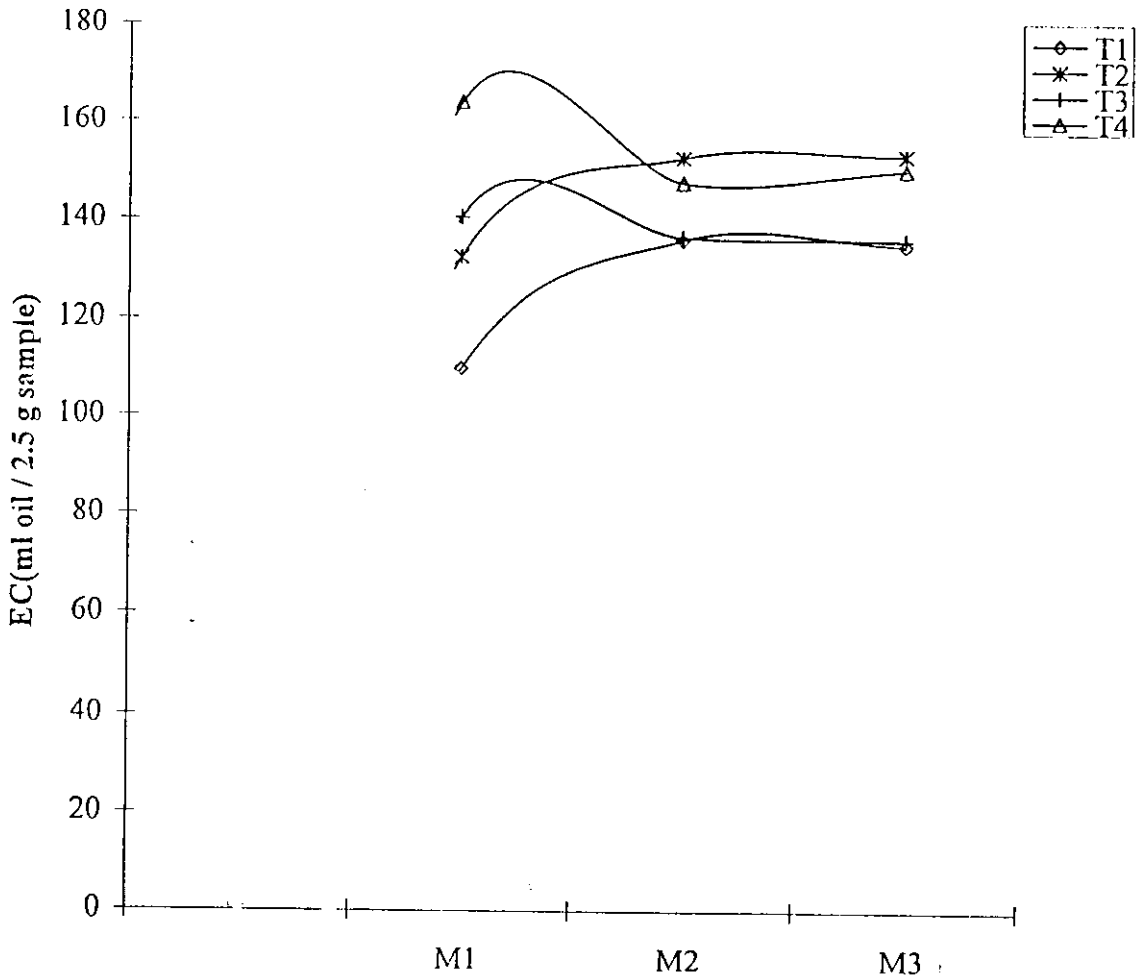

Figure (4-2): Changes in EC Values for the Different Deboning Treatments with Time

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4.3.2 Water Holding Capacity (WHC)

There were no significant differences between WHC values of the hand or mechanically deboned products; the WHC values for treatments 1,2,3 and 4 were 3.04,2.84, 2.90 and 2.83 respectively as in Table (4-5).

The values of WHC for treatments 3 and 4 were considered high (even though not significantly). This is due to the availability of more polar groups of protein due to size reduction of meat particles as well as the high pH related to the incorporation of red marrow (Demos and Mandigo, 1995).

From the table we can see that those products (with skin) from treatments 1 and 3 showed higher (not significantly) WHC values, when compared to the values of WHC in treatments 2 and 4.

Comparing the WHC values of the products of treatments 3 and 4 showed that there was no significant difference in the ability of MDM to bind water whether with skin, or skinless; which means that skin did not play a significant role and this came in agreement with (field, 1988). Also the collagen content of MDM which reached 3-4 % was much less than 15% level that have been considered detrimental to the functional properties of meat. The high pH value in MDM which came from red marrow had improved WHC of MDM.

Since mechanically deboned tissues generally have a lower protein and higher fat content, binding and water holding capacities were

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sometimes quite different from those observed in intact muscle, accordingly WHC values of both MDM or hand deboned meat were equal.

Table (4-5): Water holding capacity values for products of different deboning methods.

Treatments	WHC (g H_2O / g protein) $\bar{X} \pm$ S.D
1	3.04 ± 0.35^a
2	2.84 ± 0.14^a
3	2.90 ± 0.10^a
4	2.83 ± 0.24^a

* Means as an average of 6 readings

*Means with the same letter in the column are not significantly different.

The changes in the trend of WHC values of the different treatments during storage are shown in Table (4-6), which indicates that there was a clear decrease in the WHC values of all the treatments whether manual or mechanical deboning.

The gradual reduction in WHC values was observed in case of meat of treatments 2 and 4 which might be attributed to the lower fat content in comparison with that of treatments 1 and 3, this result could be explained by the effect of freezing on protein denaturation as in Figure (4-3).

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Table (4-6): Changes in WHC values for the samples as affected by storage time.

Treatments	WHC values after		
	1 month	2months	3 months
1	2.97^{a}	3.28^{a}	2.85^{a}
2	3.00^{a}	2.81^{ab}	2.71^{b}
3	3.01^{a}	2.82^{a}	2.87^{a}
4	3.14^{a}	2.69^{b}	2.66^{b}

* WHC expressed as g H_2O/ g protein.
* Means with the same letter at any given row are not significantly different ($P \leq 0.05$) using LSD test.
* Treatments:
1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

4.4 Lipid oxidation

Table (4-7) shows TBA values for the products from different treatments, the highest (significantly) TBA values were found in treatments 1 and 3 with values of 0.66 and 0.58 respectively, followed by treatment 4 (TBA=0.26), while the lowest TBA value was shown in treatment 2 but not significantly lower than treatment 4. The high TBA values in both treatments 1 and 3 can be explained by the presence of high fat content. Figure (4-4) demonstrates the increase of TBA values with increasing fat content.

In mechanical deboning and due to the incorporation of bone marrow fat, there will be a variation in the triglycerides (T.G) and phospholipids (PL) contents; where the T.G fraction of bone marrow lipid

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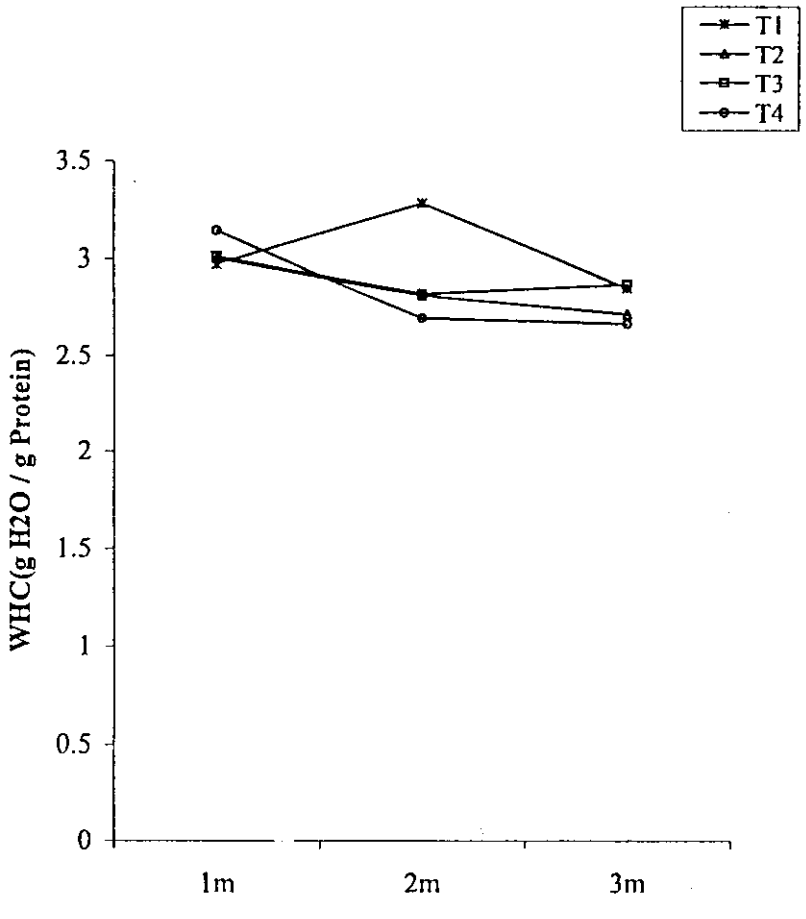

Figure (4-3): WHC Values as Affected by Storage Time

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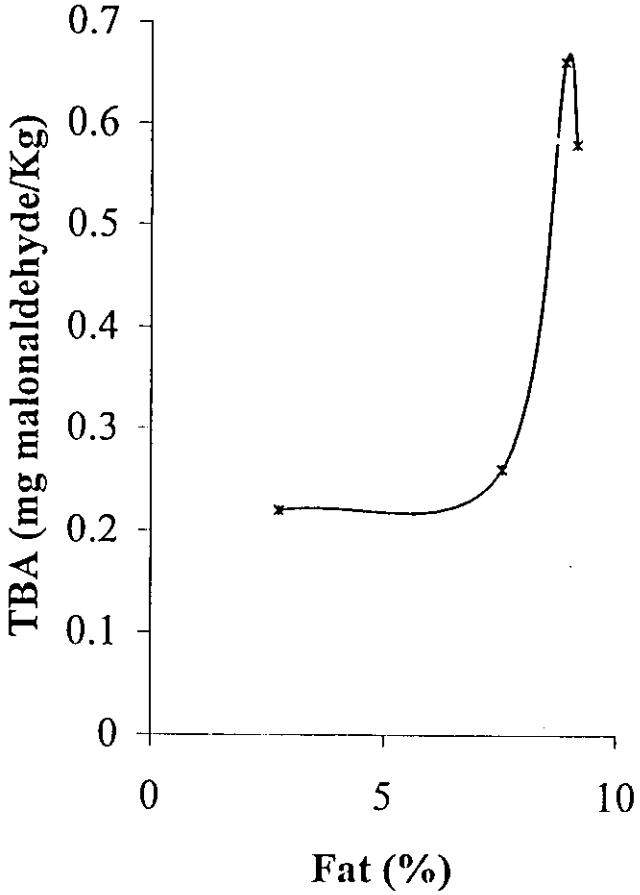

Figure (4-4): TBA- Fat Contents Relationship

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is very low in polyunsaturated fatty acids (PUSFA), and slightly lower than that of soft tissues in linoleic acid, but higher in 20:3 to 22:6 USFA. But the PL fraction of bone marrow contains high levels of polyunsaturated 20-24 carbon fatty acids. The 20-24 PUSFA comprised 27% of the total phospholipid fatty acids as compared to 1.9% for T.G fractions. Each additional double bond in PUSFA could increase the rate of autoxidation by a factor of 2. In addition the heme pigments present in bone marrow could also accelerate the oxidation of PL in bone marrow, Ca and P as anions from bone tissue have been observed acting as a catalytic agent in lipid and heme protein oxidation (Barbut *et al.*, 1985).

Also the incorporation of oxygen into the minced product during the machine deboning process, may promot the autoxidation of PUSFA located primarily in the PL of poultry tissue. In treatment 4 and as a result of removing skin, there was a significantly clear reduction in TBA value, which means that fat from bone marrow and skin contents played a major role in the lipid oxidation, this finding is in agreement with the results published by (Ang, 1988).

Also from Table (4-7), peroxide values (P.V) showed different trend from TBA values; treatment 3 showed the highest (significantly) P.V=3.90, while both treatments 1 and 4 were significantly lower in P.V with values 3.38 and 3.33 respectively. The extraction of enough fat from treatment 2 was not possible therefore PV are not available. In case of treatment 3 and

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due to the presence of fat from (skin) and fat incorporated from bone marrow, the extracted fat showed high susceptibility to oxidation, while removing skin showed a significant reduction of P.V as demonstrated in treatment4. The accepted TBA value for MDM is < 5 mg malonaldhyde / Kg as reported by (Faustman *et al.*,1992), while P.V should not exceed 5 milliequivalents oxygen per 1000g sample as reported by (Kirk and Sawyer, 1991).

Table (4-7): TBA and Peroxide values for MDM and HDM samples.

Treatments	TBA [1] $\bar{X} \pm S.D$	P.V [2] $\bar{X} \pm S.D$
1	0.66 ± 0.07^{a}	3.38 ± 1.41^{b}
2	0.22 ± 0.07^{b}	-- [3]
3	0.58 ± 0.03^{a}	3.90 ± 1.42^{a}
4	0.26 ± 0.03^{b}	3.33 ± 1.06^{b}

(1)TBA as mg malonaldehyde /Kg meat.

(2)P.V as milliequivalent oxygen per 1000g sample.

(3)Not analyzed due to difficulty in fat separation.

* Identical letters among treatments within a column denote no significant difference ($P<0.05$).

Upon frozen storage of the products, an obvious increase in both TBA and peroxide values for all the products was observed, this increase was significant for the P.V while not significant for TBA values as shown in Table (4-8). PV increased significantly between the second and the sixth week which indicated that the oxidative deterioration occurred during the

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long period of frozen storage of treatments 1 and 3 products, while in treatment 4 and due to the low fat content, the PV remained unchanged until the sixth week after which significant increase was observed.

As obvious from Table (4-8) and Figure (4-5), TBA values show no significant change for all the products , this could be explained by the fact that freezing was capable to protect the MDM and HDM from oxidation and lipid rancidity.

Table (4-8): Effect of storage time on TBA and peroxide values of the treatments samples

Treat-ments	TBA values after			Peroxide values after				
	2 weeks	6 weeks	10 weeks	2 weeks	4 weeks	6 weeks	8 weeks	10 weeks
1	0.651 ^{a}	0.620 ^{a}	0.706 ^{a}	2.045 ^{c}	2.030 ^{c}	2.395 ^{b}	2.500 ^{b}	4.140 ^{a}
2	0.195 ^{a}	0.192 ^{a}	0.286 ^{a}	--	--	--	--	--
3	0.555 ^{a}	0.586 ^{a}	0.594 ^{a}	2.475 ^{c}	2.465 ^{c}	4.380 ^{b}	4.380 ^{b}	5.030 ^{a}
4	0.300 ^{ab}	0.256 ^{b}	0.327 ^{a}	2.185 ^{b}	2.280 ^{b}	4.100 ^{a}	4.100 ^{a}	4.385 ^{a}

* Each value is a mean of 2 readings.
* Means with the same letter at any given row are not significantly different ($P \leq 0.05$) using LSD test.
* Treatments:
1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

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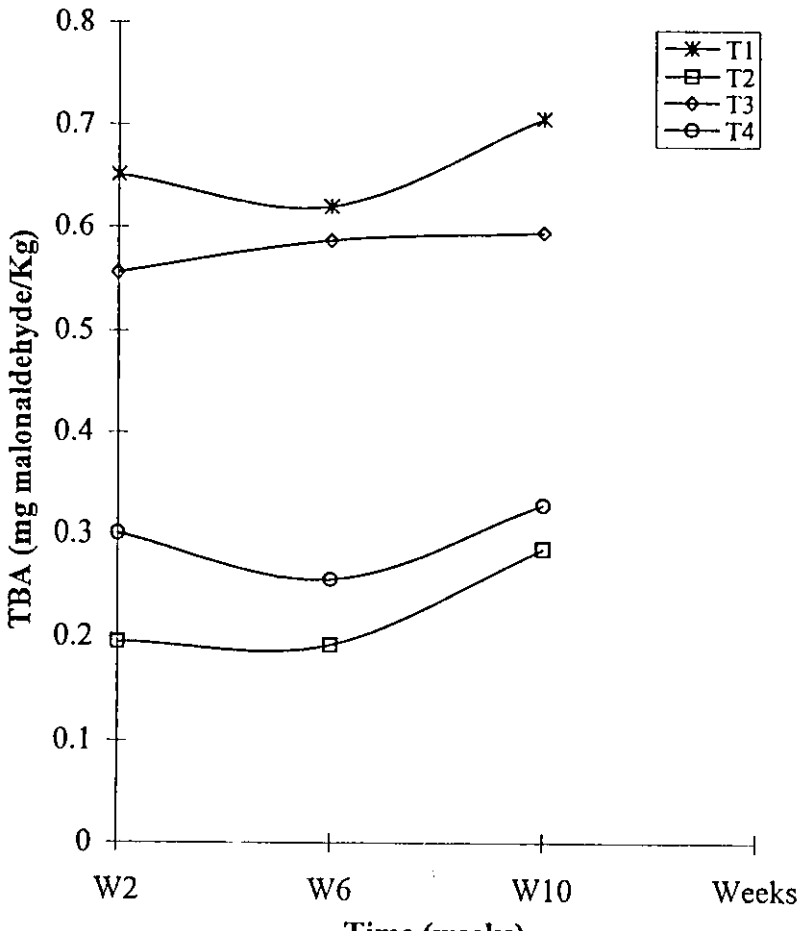

Figure(4-5): TBA Values of Different Deboning Treatments Products as Affected by Time

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4.5 Minerals content

In Table (4-9) a number of minerals showed no significant variation in it's content whether in hand or mechanically deboned products and these minerals are: Fe, Na, K and Mg. While other minerals like Ca, Mn and Zn showed significant differences in their contents; Ca content was significantly high in treatments 3 and 4 (162.5mg/100g and 230 mg/100g respectively). While in hand deboning treatments Ca content was significantly lower, (treatment 1 with 16.75 mg / 100g and in treatment 2 with 13.50 mg/100g), Mn showed the same trend in terms of being significantly higher in the mechanical treatments (3 and 4) and with value 0.055 mg / 100g and 0.045 mg /100g respectively. Treatment 1 showed also a significant high Mn value 0.045 mg / 100g , the least significant value of Mn content was in treatment 2 with 0.04mg / 100g. On the other hand Zn showed significantly higher content in treatment 4 with value 0.09 mg /100g, than in treatment 3 and may be due to the dilution effect through incorporation of skin and fat from bone, Zn reached 0.65mg/100g and this value was significantly lower than that in treatment 4, Zn values in both treatments 1 and 2 showed no significant difference as that in treatment 1 (0.40 mg / 100g) while treatment 2 with value 0.45 mg/100g,. The elements Ca, Mn and Zn were partially incorporated into the MDM from bone and bone marrow , which caused a clear elevation in their contents in treatments 3 and 4. In hand deboning treatments (1 and 2) the only sources

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of the elements were the skin and muscle tissue, according to those elements that did not show any significant differences in their quantities between hand and mechanical deboning like Fe, Na, Al, K and Mg; this un expected result may be due to the dilution effect of fat incorporated from the bone marrow. It is known that the bone and bone marrow are not a good source of these elements, this is specialy true in meat of spent hens rather than broilers in which mineral deposition is not expected like that in the broilers (Essary, 1979).

Table (4-9): Comparison of minerals content (mg/100g) of hand and mechanically deboned meat samples.

Minerals / Treatments	Fe	Na	Al	K	Mg	Ca	Mn	Zn
1	5.3^{a}	193.5^{a}	2.70^{a}	547.5^{a}	31^{a}	16.75^{b}	0.045^{ab}	0.40^{c}
2	4.6^{a}	231.5^{a}	1.30^{a}	667.0^{a}	34^{a}	13.50^{b}	0.040^{b}	0.45^{c}
3	5.5^{a}	227.0^{a}	3.85^{a}	363.0^{a}	27^{a}	162.5^{a}	0.055^{a}	0.65^{b}
4	4.2^{a}	276.0^{a}	1.15^{a}	584.5^{a}	29^{a}	230.0^{a}	0.045^{ab}	0.90^{a}

* Each values is an average of 4 readings.
** Means with the same letter at any column are not significantly different ($P<0.05$).
* Treatments:
1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

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4.6 Bone content

Calcium content was used as an indicator of the mount of bone in the meat, the calculated values are presented in Table (4-10). The bone content of the products was significantly higher in treatment 4 (0.975%) whereas in treatment 3 of 0.670%; the lower bone content value in treatment 3 may be due to the dilution effect through skin incorporation. In hand deboning treatments very small or trace amounts of bone were found (0.008%) in treatment 1 and (0.00%) in treatment 2 and this is clear in Figure (4-6). Theoretically hand deboned products should not have any bone content but sometimes the employees might miss some bone particles in the wings or thighs which gave such a result (Field, 1988).

Table (4-10): Bone and Ca contents in MD and HD meat samples

Variables	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Bone content (%)	0.008±0.001 [b]	0.00±0.0 [b]	0.670±0.24 [a]	0.975±0.13 [a]
Ca content (mg/100g)	16.75±0.35 [b]	13.50±2.12 [b]	162.5±53.0 [a]	230±29.7 [a]

* Means with the same letter at any row are not significantly different (P<.05).

* Treatments:

1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

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4.7 Meat color

In Table (4-11) the total meat pigment concentration (hemoglobin and myoglobin) of the products of the different deboning treatments are presented. The results show that the meat pigment concentration was significantly high in treatment 4 (2.590 mg / g) followed by treatment 3 (2.417 mg/g). This can be attributed the release of hemoglobin pigment from bone marrow and the variation in myoglobin state (in muscle). Skin showed a major dilution effect on the value of pigment concentration in the product of treatment 3, thus its absence (skin) had a significant effect in treatment 2 which gave a pigment concentration of 2.413 mg/g, significantly higher than that in treatment 1 (1.500 mg / g).

It is clear that with mechanical deboning and due to the incorporation of bone marrow into the product, combined with significant quantities of hemoglobin pigment might be released into the product and this would modify the color of MDM. Another effect of MD is the conversion of myoglobine in the oxyform as a result of oxygen incorporation, additionally color variation could be also due to the binding of anions to the heme pigment which might be possibly related to the amount of contact the meat had with the metal surface of the mechanical deboner (Froning, 1981; Demos and Mandigo, 1995).

The pH may play a role, the higher pH (due to bone marrow incorporation) may result in a more open or partially denatured myofibrillar

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protein structure, allowing for easier extraction of myoglobin, in addition, the pH has an effect on the iron state and consequently on the prophyrine ring structure.

Table (4-11): Pigment concentration (mg/g), Fe content (mg/100g) and fat content (%) in different deboning treatments products

Variables	Treatment 1	Treatment 2	Treatment 3	Treatment 4
Pigment X±S.D concentration	1.5 ± 0.073^{c}	2.413± 0.190^{b}	2.417± 0.280^{b}	2.59 ± 0.233^{a}
Fe content	5.30 ± 0.42^{a}	4.60 ± 0.56^{a}	5.55 ± 2.05^{a}	4.20 ± 0.56^{a}
Fat content	8.90 ± 1.27^{a}	2.75 ± 0.35^{b}	9.15 ± 0.21^{a}	7.55 ± 0.07^{a}

* Means with the same letter are not significantly different (P<0.05).

* Treatments:
1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

During storage, changes in the pigment concentration has been noticed; as in Table (4-12) which showed that with time meat color became darker. This change in meat color due to the oxidation process of the heme pigment (Field, 1988). Figure (4-7) shows the changes in meat pigment which took place with time. In hand deboning treatments the skin remained intact, no damage or fat incorporation in product occurred, thus oxidation reaction, consepuently no change in pigment concentration in treatment 1.

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In mechanical deboning and due to the presence of bone marrow fat and minerals specially cupper and iron, enhanced oxidation of pigment which lower its content.

Table (4-12): Total pigment concentration as influenced by time

Treatments	Pigment concentration after		
	1 month	2 months	3 months
1	1.445 [a]	1.490 [a]	1.565 [a]
2	2.650 [a]	2.270 [b]	2.320 [b]
3	2.775 [a]	2.200 [c]	2.275 [b]
4	2.300 [a]	2.680 [a]	2.790 [a]

* Means with the same letter at any row are not significantly different.
* Each value is an average of 3 readings.
* Treatments:
1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

4.8 Cholesterol content

In Table (4-13) the cholesterol levels in the products of the four treatments are presented. The highest level was found in the mechanically deboned samples (treatment 3) with skin (122.55 mg/100g), while lower (significantly) levels were found in both treatments 1 and 4 (78.70 mg/100g and 58.75mg/100g respectively); the lowest (significantly) level of cholesterol was found in treatment 2 (34.29 mg/100g). The major factors

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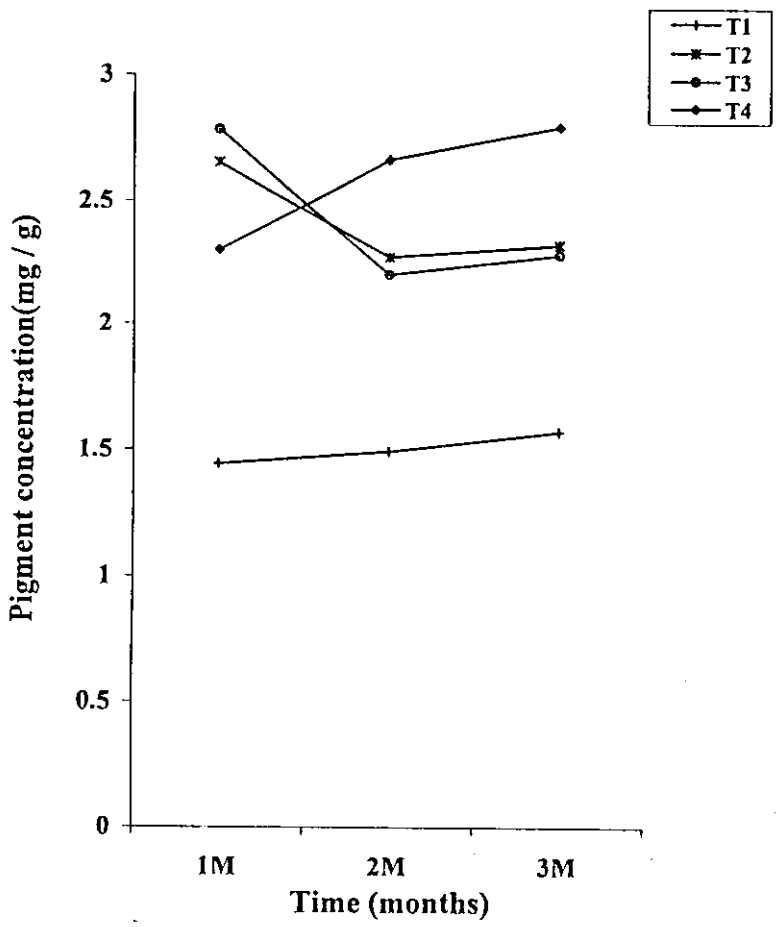

Figure (4-7): Changes in Meat Pigment Concentration of the Different Deboned Products Upon Storage

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affecting cholesterol level are: bone marrow, body fat and skin (Demos and Mandigo, 1995).

Treatment 3 which had the highest cholesterol level; had the highest fat content, due to the fat originated in marrow and skin. The cholesterol which is released from the bone marrow upon mechanical deboning, all would help in increasing the cholesterol level. Removing skin as in treatment 4 showed a very clear effect of skin removing in reducing the cholesterol level.

Hand deboning products showed a significantly lower levels of cholesterol, since no cholesterol came from bone marrow, the only source of cholesterol in treatment 2 was the body fat while in treatment 1 the skin fat is included and consequently the cholesterol level in treatment 2 product was lower. So the major factor that affect cholesterol content in hand and mechanical deboning is the bone marrow fat and cholesterol, while upon comparing the 2 types of mechanical deboning (treatments 3 and 4) or hand deboning (treatments 1 and 2) the major factor here was fat and skin as shown in Figure (4-8).

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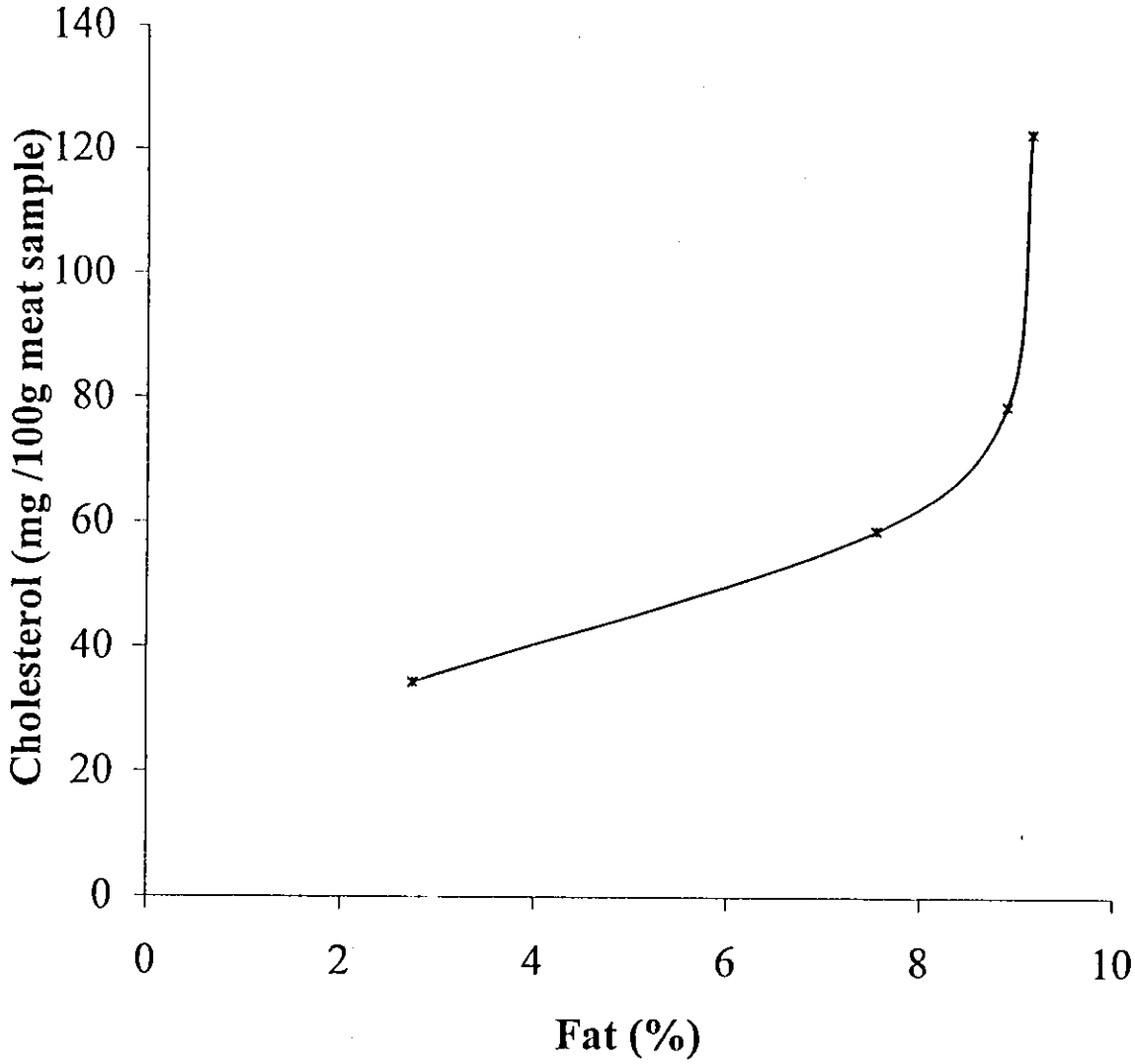

Figure (4-8): Cholesterol- Fat Relationship of the Different Deboning Treatments

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Table (4-14): Taste panel scores for the 4 deboning methods products

Treatments	After 6 weeks				After 12 weeks			
	Aroma	Color	Texture	Over all acceptance	Aroma	Color	Texture	Over all acceptance
1	6.4 [a]	6.5 [a]	5.9 [a]	6.90 [a]	7.04 [a]	5.30 [b]	6.30 [ab]	5.8 [a]
2	6.5 [a]	7.0 [a]	6.4 [a]	6.20 [a]	6.40 [ab]	7.04 [a]	6.90 [a]	7.3 [a]
3	6.3 [a]	4.31 [b]	5.9 [a]	5.04 [b]	5.40 [b]	5.77 [b]	5.41 [bc]	5.8 [b]
4	5.7 [a]	4.4 [b]	5.9 [a]	5.04 [b]	5.90 [ab]	4.90 [b]	4.50 [c]	4.5 [c]

* Means as average of 25 readings.
* Means with the same letter are not significantly different ($P<0.05$)
* Means based on a 9- point hedonic scale (9=like extremely; 1 dislike extremely).
* Treatments:

1: Manual deboning with skin
2: Manual deboning without skin
3: Mechanical deboning with skin
4: Mechanical deboning without skin

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CHAPTER FIVE

CONCLUSIONS

AND

RECOMMENDATIONS

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5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1- Mechanical deboning gave the highest yield and efficiency when compared with hand deboning methods whether in deboning the whole carcasses or the skinless carcasses.

2- The proximate composition of the deboned samples showed that MDM have high fat, lower moisture and protein contents, the ash content was significantly higher in MDM -whether with skin or not- than the hand deboned meat.

3- pH and collagen content values were significantly higher in MDM than HDM.

4- Emulsifying capacity values showed that treatments 2 and 4 have highest EC values, while in treatment 1 gave the lowest value. With frozen storage MDM showed a reducing trend in EC values, while HDM showed a significant increase in EC values.

5- No significant differences in the WHC values between HDM and MDM was observed; the WHC values of all the treatments showed a reduction trend upon frozen storage.

6- TBA test showed that the higher TBA value were in treatments 1 and 3, whereas peroxide value was the highest in treatment 3, with time

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TBA values showed no significant increase for all the treatments, while peroxide value showed a significant increasing trend for all treatments.

7- Fe, Na, Al, K and Mg contents showed no difference between MDM and HDM, while significantly higher Ca, Mn and Zn contents were found in MDM than in HDM. In addition bone content in MDM was significantly higher than that in HDM.

8- Meat pigment concentration was significantly the highest in treatment 4 followed by treatment 3 and then 2, while the least pigment concentration was in treatment 1, with time meat color become darker due to oxidation.

9- Higher cholesterol levels were found in MDM.

10- Hand deboned meat showed better sensory quality than MDM, throughout the storage period.

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5.2 Recommendations

1- The use of MDM in the various comminuted meat products, particularly in emulsion type sausages, due to the high yield and deboning efficiency, which gives us a cheaper meat source is recommended.

2- MDM showed better functional properties like emulsifying capacity, water holding capacity, color and TBA stability, which give the MDM advantages over HDM when incorporated in meat products.

3- Recommending the use of MDM at its early shelflife period as it maintains better functional properties and storage stability.

4- MDM pigment concentration could be used as an indicator to identify MDM incorporated in meat product made from other meat sources.

5- Proper adjustment and maintenance of the deboning machines is recommended to obtain a meat with minimum bone content and to reduce variations between batches.

6- Where it is economically feasible (possible), it is better to use skinless carcasses to reduce collagen content and oxidation rate, to increase emulsifying capacity and color acceptability.

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APPENDIX 1

Evaluation of Minced Chicken Meat Samples

Name: Date: .....

Please evaluate these samples and check how much you like or dislike each of their characteristics using a 9-point line hedonic scale in your evaluation.

Characteristics to be evaluated:-

1. Color

Samples:

148: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Like extremely — Dislike extremely

914: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Like extremely — Dislike extremely

579: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Like extremely — Dislike extremely

414: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Like extremely — Dislike extremely

* * *

2. Aroma:-

148: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Like extremely — Dislike extremely

914: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Like extremely — Dislike extremely

579: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Like extremely — Dislike extremely

414: ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Like extremely — Dislike extremely

* * *

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ملخص باللغة العربية

تأثير عمليات الجرم الميكانيكي واليدوي على صفات لحم دجاج البيض المنتهي الكامل والمنزوع الجلد

إعداد

رلى عواد النجداوي

المشرف

الدكتور باسم العبدالله

يرافق ارتفاع أسعار اللحوم الحمراء في الأردن وهي المادة الرئيسية الداخلة في تصنيع اللحوم، سعي أصحاب الصناعة إلى تقليل كلفة تلك المنتجات، لذلك يقوم المصنّعون المحلّيون باستغلال ذبائح دجاج البيض رخيصة الثمن كمادة أولية في منتجات اللحوم المستحلبة والمفرومة.

تم تحضير عينات من دجاج البيض المنتهي حيث تمت عملية الجرم لها بأربع معاملات مختلفة وهي: ١) جرم يدوي للدجاج الكامل، ٢) جرم يدوي للدجاج منزوع الجلد، ٣) جرم ميكانيكي للدجاج الكامل ، ٤) جرم ميكانيكي للدجاج منزوع الجلد. وقد تم تعبئة اللحوم في أكياس بولي إيثيلين وجمدت وتم تخزينها على درجة حرارة-١٨ْس. دُرِس التركيب التقريبي

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والذي يشمل البروتين الخام والدهن والرماد والرطوبة، كما تم تحديد الكالسيوم والرقم الهيدروجيني والصفات الوظيفية المهمة ومنها: قابلية اللحوم على الاستحلاب، حيث وجد بأن المعاملات ٤ و٢ ذات المحتوى الأقل من الدهن لها مقدرة أعلى على الاستحلاب إذ كانت ١٥٣,٨ مل زيت/٢,٥ غم عينة و ١٤٦ مل زيت/٢,٥ غم عينة على التوالي. كذلك درست مقدرة اللحوم على الاحتفاظ بالماء ووجد بأنها لا تختلف معنوياً بين منتجات المعاملات الأربع ولكن وجد بان القيم الأعلى كانت في منتجات المعاملات ١ و ٣ والتي احتوت على أعلى نسبة من الدهن، سُجّل انخفاض في مقدرة اللحوم على الإحتفاظ بالماء أثناء فترة التخزين.

قُدّرت قيم رقم حمض الثيوباربتيوريك ورقم البيروكسيد كمقياس التزنخ التأكسدي في عينات المعاملات الأربع، و أظهرت نتائج فحص رقم حمض الثيوباربتيوريك بأن المعاملات ١ و ٣ ذات المحتوى الأعلى من الدهن أعطت قيماً أعلى، بينما المعاملات ٢ و ٤ أعطت قيماً أقل بفروق معنوية، أما نتائج رقم البيروكسيد فقد أظهرت بأن لحوم المعاملة ٣ كان لها أعلى قيمة نظراً لارتفاع نسبة اللاإشباع في محتواها الدهني نتيجة لوجود دهون نخاع العظم والجلد فيها، بينما أعطت منتجات المعاملات ١ و ٤ قيماً أقل بفروق معنوية.

تم تقدير محتوى اللحوم من العناصر المعدنية، ووجد بأن العناصر: الحديد والصوديوم والألمنيوم والبوتاسيوم والمغنيسيوم لا تعطي أي اختلاف معنوي في قيم محتواها لمنتجات

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المعاملات الأربع، ولكن بعض العناصر مثل الكالسيوم والزنك والمنغنيز كانت قيمـــها أعلـى معنوياً في المعاملات ٣و٤، مقارنة بالمعاملات ١و٢. تم تقدير كمية العظم المتبقي فـي لحـوم المعاملات الأربع ووجدت أعلى معنوياً في معاملات الجرم الميكانيكي، بينما كانت أقـل فـي معاملات الجرم اليدوي.

تم تقدير تركيز صبغة اللحم لعينات المعاملات الأربع، ووجد بأن الصبغة أعلى تركـيزاً في منتج المعاملة ٤ إذ بلغت ٢,٥٩ ملغم/غم تلاها المعاملات ٣ و ٢ بمقدار ٢,٤١٧ ملغم/غم و ٢,٤١٣ ملغم/غم على التوالي دون أن تكون الفروق معنوية، بينما بلغ تركـيز الصبغـة فـي المعاملة ١ مقدار ١,٥ ملغم / غم بفروق معنوية مع المعاملات الأخرى.

تم تحديد محتوى اللحوم من الكولستيرول للمعاملات الأربع ووجد بأنه يتناسب طرديـاً مع محتوى هذه اللحوم من الدهن بحث أعطى منتج المعاملة ٣ أعلـى قيمـة معنويـة بلغـت ١٢٢,٥٥ ملغم/١٠٠غم، تلاها منتجات المعاملات ١ و ٤ بقيم ٧٨,٧٠ ملغم /١٠٠غم و ٥٨,٧٥ ملغم /١٠٠غم على التوالي، واحتوت المعاملة ٢ على أقل نسبة مـن الكولسـتيرول إذ بلغـت ٣٤,٢٩ ملغم/١٠٠غم.

تم إجراء تقيم حسي شمل الرائحة واللون والقوام والتقبل العام للحوم الناتجة بعد ٦ و ١٢ أسبوعاً من التخزين، ولم توجد أية فروق معنوية في درجات تقييم الرائحة للحوم المجرومة

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يدوياً بعد٦ و ١٢ أسبوعاً بينما وجد بأن لحوم المعاملة ٣ أظهرت انخفاضاً معنوياً في درجات تقييم الرائحة بعد ١٢ أسبوع من التخزين، أما درجات تقييم اللون فقد أظهرت بأن اللحوم المجرومة يدوياً قد حصلت على قيم أعلى من اللحوم المجرومة ميكانيكياً.

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