

CHEMICAL ANALYSIS OF MECHANICALLY  
PROCESSED BEEF

By

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CHEMICAL ANALYSIS OF MECHANICALLY  
PROCESSED BEEF

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## CHAPTER I

### INTRODUCTION

As a result of the expanding world population, there has been an increased emphasis on developing new ways of meeting the ever-growing demand for food. Many different approaches have been investigated in hopes of developing new or additional food sources. Materials not traditionally used as food in many parts of the world are now gaining wide acceptance. The problem of meeting the world demand for food has triggered an all out search for new food sources, better utilization of existing sources, and means of reducing waste of available materials. However, until only recently, one major source has been over-looked--that of mechanically processed red meat.

The meat industry has recently utilized new non-meat materials by combining them with traditional meat ingredients to process new products that are appealing to the consumer. The mechanical-deboning process allows the recovery of meat and marrow from bones of beef, pork, and lamb which would otherwise be rendered as inedible. This food source amounting to approximately 2,090,757 metric tons of mechanically-deboned meat (1) has been wasted in the past. A large percentage of the loss is due to the difficult task of hand-stripping the backbones, ribs, and neckbones of slaughter animals. Not only is it practically impossible to remove all of the meat from such bone structures, but it is also economically unfeasible from the labor

standpoint (2). With the aid of a mechanical deboning machine, however, each bone could be stripped of all meat, thus resulting in a possible gain of 13 to 16 additional pounds of meat per beef carcass.

The mechanical-deboning process also results in the incorporation of microscopic bone particles in the final product. These particles are composed of calcium, phosphorus, and a variety of trace minerals. The human diet is usually lacking in the required amount of calcium (3, 4). Therefore, since the retention of calcium from bone sources is high, mechanically processed meat may be helpful in balancing the calcium:phosphorus ratio and thus, preventing calcium deficiencies in the diet.

The bone marrow, which is liberated during the mechanical-deboning process, adds yet another nutrient lacking in hand-deboned meat, that of ascorbic acid. Bone marrow contains relatively high amounts of this vitamin as well as iron and a number of trace minerals. Data collected at the University of Wyoming indicated that most mechanically processed red meat produced commercially contains two to three mg of ascorbic acid per 100 g meat on a fresh weight basis. Knox (5) also observed that ischaemic heart disease is inversely related to the intake of calcium and ascorbic acid in the diet.

This evidence leads one to believe that mechanically processed meat (MPM) is beneficial from the nutritional standpoint. However, heavy minerals such as lead and fluorine are also known to collect in the bone. Such minerals when consumed in large amounts can produce toxicity. Therefore, before mechanically processed meat can be widely distributed on the consumer market, its chemical composition needs further researching to determine the actual nutritive value of the meat.

## Purpose and Objectives

The purpose of this study was to analyze the chemical composition of mechanically processed beef and compare its nutritive value with that of hand-deboned meat thus ascertaining the variations in nutritive quality that occur as a result of the processing technique being utilized. The researcher did not analyze the hand-deboned meat to determine its nutritive value, but instead utilized the works of previous researchers who had reported their results in this area.

The following objectives were developed for the study:

1. To analyze the calcium, phosphorus, magnesium, manganese, zinc, iron, chromium, copper, lead, and potassium content of mechanically processed beef. These values will then be compared to the amounts found in hand-deboned beef to determine which sample contains the highest percentage of available specified nutrients.
2. To analyze the fat content and fatty acid composition of the mechanically processed beef so as to determine the ratio of polyunsaturated to saturated fat, and thus establish a comparison between the two deboning methods.
3. To determine the nitrogen content of mechanically processed beef and make a comparison of the total percent of protein available in the two types of meat.

## Hypotheses

The following hypotheses gave the research focus. They are:

- $H_1$ : There will be significant differences in the nutritive content of the two meats. The mechanically processed meat

will be higher in calcium, phosphorus, magnesium, manganese, zinc, iron, chromium, copper, lead, and potassium than the hand-deboned meat.

H<sub>2</sub>: The mechanically processed meat will contain significantly more unsaturated fat than the hand-deboned meat.

H<sub>3</sub>: After determining the total nitrogen content of the meat sample, it will be found that the hand-deboned meat will contain a somewhat greater percentage of nitrogen than the mechanically processed sample.

#### Assumptions

The study was planned and conducted in accordance with the following assumptions:

1. The mechanically processed meat under investigation has been prepared in accordance with the standards specified in the Federal Register, Volume 41, No. 82, page 19762, April 27, 1976, for Class 7, Mechanically-Deboned Meat.
2. The mechanically processed meat has been prepared under proper conditions as specified in MPI Bulletin 76-111 issued July 6, 1976 by the United States Department of Agriculture.
3. The mechanically processed meat has been stored according to the regulations outlined in MPI Bulletin 76-111 issued July 6, 1976 by the United States Department of Agriculture.

#### Definition of Terms

For the purpose of this study, the following definitions were used:

Dependent Variables--the conditions or characteristics that somehow change as the experimenter manipulates the independent variable (8).

Independent Variables--the conditions or characteristics which are manipulated in order to ascertain their relationship to observed phenomena (8).

Mechanically Deboned Meat--

. . . the product resulting from the mechanical separation and removal of most of the bone from attached skeletal muscle tissue, and containing a minimum of 14.0 percent protein with a minimum Protein Efficiency Ratio value of 2.5, a maximum fat content of 30 percent, and a maximum calcium content of 0.75 percent (6).

Mechanical Deboning--a process which separates meat and some bone marrow from bones (1).

Protein Efficiency Ratio (PER)--a measure of the weight gain of a growing animal divided by protein intake (9).

Mechanically Processed Beef--the new nomenclature used to describe the mechanical separation and removal of most of the bone from attached skeletal muscle tissue. This product was formerly known as mechanically deboned meat.

## CHAPTER II

### REVIEW OF LITERATURE

This chapter contains a review of information from a collection of articles related to mechanically processed meat. The mechanical processing technique, as well as some possible reasons for the variations often seen in the meat product are discussed. Some of the nutrients found in mechanically processed beef and their contribution to the diet are also briefly discussed.

#### Mechanical Processing Technique

The mechanical processing technique is not new. Such procedures have been in use in the poultry industry for nearly 12 years and even longer in the fish industry. As a result, millions of pounds of protein have been retained as a valuable food source. Due to the nature of the bones of red-meat animals and the nature of the industry itself, however, it has not been until several years ago that the equipment for red-meat deboning has been developed to the point where its use can be considered for approval by the United States Department of Agriculture (10). Since that time, researchers have been investigating and exploring the area of mechanically processed meat, but large gaps in the knowledge concerning its use are still present.

The Meat and Poultry Inspection Program of the United States Department of Agriculture has done considerable research in this area.

After several years evaluation, the Program staff concluded that a sufficient basis existed for rule-making on the use of mechanically processed red meat (11). It was also decided that the term "meat" should be redefined so as to include mechanically-deboned meat (now referred to as mechanically processed meat) in its definition. As stated in the Federal Register, Volume 41, No. 82, Tuesday, April 27, 1976, p. 17535,

The proposed redefinition of 'meat' appears to be especially appropriate at this time, since the world wide food shortage, especially of protein, makes it mandatory that all available food be retained for consumption.

The revised definition reads as follows:

§ 301.2 Definitions.

(tt) Meat. Any edible portion of the carcass of any cattle, sheep, swine, or goats, exclusive of lips, snouts, ears, caul fat, leaf fat, kidney fat, and other visceral fat, and exclusive of all organs, except the heart, tongue, and esophagus; and including but not limited to the following classes of meat:

- (1) Skeletal meat,
- (2) Heart meat,
- (3) Tongue meat,
- (4) Esophagus meat,
- (5) Meat trimmings,
- (6) Fatty meat trimmings,
- (7) Mechanically deboned meat,
- (8) Mechanically deboned meat for processing,
- (9) Mechanically deboned meat for rendering,
- (10) Rendered meat,
- (11) Rendered meat for processing,
- (12) Cooked rendered meat, and
- (13) Cooked rendered meat for processing (6, p. 17561-17562).

A proposed regulation concerning the manufacture and use of mechanically deboned meat was also published in the Register under the title, "Definition of Meat and Classes of Meat, Permitted Uses, and Labeling Requirements." In it, the three different classes of mechanically-deboned meat--(1) mechanically-deboned meat,

(2) mechanically-deboned meat for processing, and (3) mechanically-deboned meat for rendering--are defined. The definitions, as outlined in § 319.5 Definitions of Classes of Meat (6, p. 17562), are as follows:

Class 7: Mechanically Deboned Meat--the product resulting from the mechanical separation and removal of most of the bone from attached skeletal muscle tissue; and containing a minimum of 14.0 percent protein with a minimum Protein Efficiency Ratio (PER) value of 2.5 (or an essential amino acid content of 33 percent), a maximum fat content of 30 percent, and a maximum calcium content of 0.75 percent.

Class 8: Mechanically Deboned Meat for Processing--the product resulting from the mechanical separation and removal of most of the bone from attached skeletal muscle tissue and which fails to meet one or more of the limits prescribed for class 7, but contains a minimum of 10.0 percent protein with a minimum PER value of 2.5 (or an essential amino acid content of 33 percent), and a maximum calcium content of 1.0 percent.

Class 9: Mechanically Deboned Meat for Rendering--the product resulting from the mechanical separation and removal of most of the bone from attached skeletal muscle tissue and which fails to meet one or more of the limits prescribed for class 8.

The Register also includes the definition of "Rendered Meat" as follows:

Class 10: Rendered Meat--the product resulting from the partial removal of fat from meat of class 1, 2, 3, 4, 5, 6, 7, 8, or 9, or a combination thereof, by a low temperature (120° F. or less) rendering process, and containing a minimum of 14 percent protein with a minimum PER of 2.5 (or an essential amino acid content of 33 percent), a maximum fat content of 30 percent, and, if mechanically deboned meat is used, a maximum calcium content of 0.75 percent . . . .

Table I summarizes the standards as they were proposed for each class of mechanically-deboned meat. Corresponding values of hand-deboned meat as outlined in available literature were also listed in Table II so as to provide the reader with a means of comparison between the two products.

TABLE I  
NUTRITIONAL QUALITY STANDARDS FOR  
MECHANICALLY-DEBONED MEAT

Product	Minimum Protein Content (%)	Minimum PER	Min. Essen. Amino Acids	Max. Fat Content (%)	Max. Calcium Content (%)
			Content (% of Total Protein)		
Mechanically-Deboned Meat					
Interim Regulation	14	2.5	32	30	0.5
Proposed Regulation	14	2.5	33	30	0.75
Mechanically-Deboned Meat for Processing					
Interim Regulation	10	2.5	32	60	0.75
Proposed Regulation	10	2.5	33	--	1.00

Source: R. A. Field, "Mechanically-Deboned Red Meat," Food Technology (1976).

TABLE II  
NUTRITIONAL QUALITY OF GROUND BEEF

Product	Average Protein Content (%)	Average PER	Essential Amino Acids (% of Protein)	Fat Content (%)	Calcium Content (%)
Regular Ground Beef	16.24	2.52	38.46	25.28	0.01

Source: H. R. Cross, J. Stroud, Z. L. Carpenter, A. W. Kotula, T. W. Nolan, and G. C. Smith, "Use of Mechanically Deboned Meat in Ground Beef Patties," Journal of Food Science (1977).

As previously stated, the mechanical-deboning machinery which is presently on the market has the potential of saving all the lean, red meat that would otherwise end up as by-products. It is most useful for stripping the meat from neckbones, backbones, ribs, and other such difficult bones to clean by hand-deboning methods.

The resulting product is somewhat redder than regular ground beef because of the increased heme content from marrow and because much of the white connective tissue is strained out with the large bone fragments. As compared with plain muscle meat, MDM contains more of the normal constituents of bone and marrow and less of the low-quality protein connective tissue (12, p. 501).

The process itself involves feeding the bones (and any attached meat) into the machine where they are then chopped and shredded. Pressure is applied which forces the meat through a stainless steel screen containing very small conical holes so as to produce a fine-ground meat. This allows a certain amount of pulverized bone as well as bone marrow to come through the machine with the resulting meat fraction. In examining the output from the machines, it was found that both the quantity of bone and the size of the particles were satisfactory in every respect. The bone particles ranged in size from 0.001 to 0.018 inches (10). This suggested that the particles in mechanically processed meat would not represent any hazard, but would instead be dissolved by the stomach acid and provide an additional source of calcium (11). Fried (10) also reports that the risk of mechanical damage, piercing, and abrasion is much less in mechanically processed meat than in its hand-deboned counterpart due to the fact that the use of sharp knives to cut around bones often leads to the incorporation of bone slivers and chips in the hand-deboned product.

The incorporation of these microscopic particles in the final product led to a great deal of controversy among consumer groups around the nation. More than 1100 comments were received in response to the United States Department of Agriculture's proposed regulations--many questioning the health and safety aspects of the product. As a result, a coalition of consumer-oriented organizations and the Attorney General of Maryland took legal steps to have the interim regulations repealed. Thus, as of September 10, 1976, a Preliminary Injunction was placed on the manufacture of mechanically processed meat which resulted in a complete halt to its production. Until that time, 1.6 million pounds of mechanically processed meats were being produced and used weekly in products by 43 companies (15). But, until further research proved otherwise, mechanically processed meat was to be considered "adulterated and an adulterant" (11, p. 5). This injunction spurred further research in the area of mechanically processed meat. The nutritional benefits as well as safety aspects of mechanically processed meat are now being more fully investigated.

#### Nutritional Value

Many investigators (2, 13, 16, 17, 18, 19, 20, 21, 22) recently confirmed the fact that differences in nutritive value between mechanically processed meat and hand-deboned meat do exist. These differences are due to the incorporation of fine bone particles and bone marrow into mechanically processed meat as well as to the elimination of some of the collagen from the meat.

### Calcium

Probably the greatest significant difference in mechanically processed meat and hand-deboned meat is the calcium content. Many factors affect the percentage of this mineral's availability, but it was reported that recent analyses of MPM for calcium indicated a concentration of 0.5 percent in most samples of red meat (11). Watt and Merrill (23) determined the calcium content of hand-deboned meat to be very low (0.01 percent) with this amount being relatively constant. Therefore, any significant increase in calcium indicates an increase in bone particles.

The Recommended Dietary Allowance (RDA) for calcium as determined by the Food and Nutrition Board of the National Research Council (24) is 800 mg per day for adults and for children from ages one to 10 years. From the ages 11 to 18 years the requirement is increased to 1200 mg calcium per day. However, a number of studies showed that the average American diet tended to fall short of the recommended allowance for this important mineral (25, 26, 27, 28). The 1965 Household Food Consumption Survey found that the average calcium intake for females after age 12 was less than 75 percent of the RDA, and the intake for both men and women, 35 years of age and older, was only 2/3's or less. The other surveys previously cited reported similar findings. Therefore, since the retention of calcium from bone sources is high (29, 30), mechanically processed meat is beneficial from a dietary standpoint.

Persons with osteoporosis may require an even greater amount of calcium per day. Spencer, H., Kramer, L., Norris, C., and Osis, D., (31) reported that long-term calcium studies of adult subjects revealed

that about 50 percent of them were in negative calcium balance even while ingesting 800 mg calcium per day. Those subjects who failed to maintain calcium equilibrium at the 800 mg calcium intake level were persons with subclinical or overt osteoporosis. When the dosage was increased to 1200 mg per day, an average positive calcium balance was also achieved. In addition, it was found that further increases in the calcium level of the diet (to as much as 2200 mg per day) did not result in any further calcium retention. This tends to indicate that the body does not absorb excess calcium when it is not needed by the body.

There is no evidence to indicate that a high calcium intake leads to soft tissue calcifications in man. This process depends on many factors, most of which are still not understood. One may, however, assume that this may occur, if the high calcium intake were taken together with a large dose of vitamin D (11, p. 18).

There is, however, a small percentage of the population which requires a low calcium intake for medical reasons. Such persons as kidney stone formers may be hyper-absorbers of calcium. This would lead to a higher excretion of calcium in the urine, which could possibly promote the formation of kidney stones. Therefore, it is suggested that appropriate labeling of the meat products containing mechanically-deboned meat be required so as to allow such individuals the choice to avoid purchasing the items (11).

The Select Panel, convened at the request of the Administrator of the Animal and Plant Health Inspection Service, estimated the risk/benefit ratio of the increased calcium intake due to the ingestion of meat products containing mechanically processed meat in persons with normal calcium metabolism. On the basis of consumption data, the

Panel projected the intake of calcium due to the intake of meat products containing mechanically processed meat. The data they obtained is shown in Tables III and IV. The calcium intakes are presented as calcium intake per kilogram body weight and also as calcium intake in milligrams per day. In calculating the data, it is assumed that the meat product contained 20 percent mechanically processed meat by weight, and the calcium concentration is 0.5 percent.

After careful study, the Panel concluded that:

The intake of the very small amounts of calcium resulting from the intake of mechanically deboned meat represents negligible increases in the daily calcium intake and cannot be considered hazardous. Should the calcium intake be higher because of the intake of greater amounts of MDM, this increased intake can be considered beneficial, as a large sector of the population may not consume an optimum or adequate amount of calcium. The additional calcium intake would be beneficial for persons maintained on a high calcium intake, for those who have osteoporosis and for those who receive long term treatment with medications which induce a loss of calcium (11, p. 25)

#### Differences in Calcium Content

Factors which affect the amount of calcium (bone particles) in the final product were reported by Field, Riley, and Corbridge (32) and Field (1). These factors included the yield of meat in the original product, the design of the deboning equipment, amount of meat attached to the bone at the time of deboning, type of bone, and the extent to which the bones were broken prior to mechanical deboning.

An analysis of the calcium content of mechanically-deboned mutton and lamb carcasses showed that a greater percentage of calcium was obtained when the mechanical deboner was adjusted to produce the greatest yield of meat (17). These investigators reported that the calcium and fat content was extremely low (0.09 percent and 8.62

TABLE III  
PROJECTED CALCIUM INTAKE DUE TO MDM<sup>1</sup> 90TH PERCENTILE MDM  
INTAKE AND AVERAGE CALCIUM CONCENTRATION IN MDM

Age Range yrs	Body Weight kg	Meat Group	Meat Intake		MDM Intake		Calcium Intake	
			gm/kg	gm/day	mg/kg	mg/day	mg/kg	mg/day
0-2	12.194	Total Meat	1.279	16	153.510	1872	0.90570	11
		Meat w/o Baby-J	0.320	4	60.148	733	0.35487	4
		Meat w/o Hambgr.	1.122	14	134.681	1642	0.79461	10
		Meat w/o B-J, HB	0.194	2	33.029	403	0.19487	2
3-5	17.911	Total Meat	0.719	13	134.985	2418	0.79641	14
		Meat w/o Hambgr.	0.457	8	73.334	1313	0.43267	8
6-12	32.710	Total Meat	0.813	27	145.119	4747	0.85620	28
		Meat w/o Hambgr.	0.490	16	76.429	2510	0.45093	15
13-17	56.129	Total Meat	0.583	33	107.470	6032	0.63407	36
		Meat w/o Hambgr.	0.333	19	49.735	2792	0.29344	16
18-24	65.310	Total Meat	0.506	33	96.399	6296	0.56875	37
		Meat w/o Hambgr.	0.200	13	27.201	1776	0.16049	10
25-44	70.153	Total Meat	0.430	30	80.556	5651	0.47528	33
		Meat w/o Hambgr.	0.220	15	30.403	2133	0.17938	13
45 +	71.325	Total Meat	0.345	25	65.235	4653	0.38489	27
		Meat w/o Hambgr.	0.164	12	22.248	1587	0.13126	9

<sup>1</sup>MDM contained in meat products in amounts equal to 20 percent of the meat block

Source: "Health and Safety Aspects of the Use of Mechanically Deboned Meat" 1977.

TABLE IV  
PROJECTED CALCIUM INTAKE DUE TO MDM<sup>1</sup> AVERAGE MDM INTAKE  
AND AVERAGE CALCIUM CONCENTRATION IN MDM

Age Range yrs	Body Weight kg	Meat Group	Meat Intake		MDM Intake		Calcium Intake	
			gm/kg	gm/day	mg/kg	mg/day	mg/kg	mg/day
0-2	12.194	Total Meat Groups	0.376	4.58	51.822	631.92	0.29800	3.63
		Meat w/o Baby-J	0.132	1.61	22.439	273.62	0.13054	1.59
		Meat w/o Hambgr.	0.324	3.95	41.388	504.69	0.23644	2.88
		Meat w/o B-J, HB	0.079	0.96	12.006	146.40	0.68980	0.94
3-5	17.911	Total Meat Groups	0.356	6.38	62.463	1118.77	0.36305	6.50
		Meat w/o Hambgr.	0.199	3.56	31.009	555.40	0.17748	3.18
6-12	32.710	Total Meat Groups	0.363	11.87	62.538	2045.61	0.36249	11.86
		Meat w/o Hambgr.	0.200	6.54	29.803	974.86	0.16936	5.54
13-17	56.129	Total Meat Groups	0.277	15.55	47.217	2650.24	0.27097	15.21
		Meat w/o Hambgr.	0.140	7.86	19.749	1108.49	0.10891	6.11
18-24	65.310	Total Meat Groups	0.206	13.45	36.563	2387.93	0.20998	13.71
		Meat w/o Hambgr.	0.079	5.16	11.183	730.36	0.06024	3.93
25-44	70.153	Total Meat Groups	0.191	13.40	32.560	2284.18	0.18697	13.12
		Meat w/o Hambgr.	0.091	6.38	12.699	890.87	0.06979	4.90
45 +	71.325	Total Meat Groups	0.152	10.84	25.969	1852.24	0.14656	10.45
		Meat w/o Hambgr.	0.069	4.92	9.391	669.81	0.04875	3.48

<sup>1</sup>MDM contained in meat products in amounts equal to 20 percent of the meat block

Source: "Health and Safety Aspects of the Use of Mechanically Deboned Meat" 1977.

percent respectively) when the ring valve of the Beehive AUX 70 Model deboner was set to obtain 52 percent of the mutton carcass weight as boneless lean. After tightening the ring valve to yield 70 percent boneless meat from mutton carcasses, the calcium content increased to 0.20 percent, and the fat content increased to 17.10 percent. After tightening the valve a third time to increase the yield to 84 percent boneless meat, it was found that the calcium and fat content increased to 0.27 percent and 24.93 percent respectively (17). These higher percentages of calcium and fat were due to the fact that less bone was discarded from the machine when it was operated at the higher setting than was discarded when the value was adjusted to produce a lesser yield of meat (17).

Field and Riley (17) have also reported that the design of mechanical deboner being utilized can have further influence on the calcium content of the meat. Goldstrand (19) also found this to be true. However, he stated that the design had little influence on protein, fat, or moisture content.

#### Other Nutrient Components of Bone

Bone also supplies many other essential nutrients required for the attainment of health (33). Copper, magnesium, zinc, phosphorus, manganese, iron, and fluorine, as well as ascorbic acid, are known constituents of either the bone or its marrow (34). Guyton (34) also reported that chromium and lead are known to collect in the bone marrow. Therefore, the amount of bone material incorporated into the mechanically processed meat also has an influence on the amounts of these nutrients present.

Because some of the nutrients are known to produce toxicity when consumed in excessive amounts (35), concern has been voiced as to whether unacceptable levels are present in the finished product. Fried (10) stated however, that a search of the literature and discussion with researchers in government and elsewhere indicated that no apparent problem exists.

### Fluoride

Field (13) reported that mechanically processed meat obtained from animals grazed in areas where vegetation is naturally high in fluorides may have fluoride contents ranging from seven to 16 micrograms per gram meat. Since the fluoride toxicity level, as estimated by the Food and Nutrition Board (24), is 20 to 80 mg or more, this does not tend to pose a problem. Waldbott (36) and Marier and Rose (37) also found that even when mechanically processed meat came from areas where the water or vegetation was relatively high in fluoride, the fluoride content in MDM was still considerably lower than that found in other foods. The proposed legal limitation on maximum calcium levels (6), in effect, limits the amount of boney material that can be incorporated in mechanically processed meat. Because the increased fluoride levels are also associated with the boney material, the calcium limit also limits fluoride. Field (13), therefore, concluded that under these conditions, the fluoride would not approach toxic levels. In fact, products which contain mechanically processed meat should be of value in furnishing the needed amount of fluoride and in reducing the incidence of tooth decay (13). Knight and Winterfeldt (12) also stated that beneficial intakes of fluoride may result

from the use of MDM in areas of the United States where the intake is low or water is not fluoridated.

#### Ascorbic Acid

The deboning equipment also removes some of the bone marrow which then becomes a part of the final mechanically processed meat product. Nutritionally, this addition is beneficial. Meat has practically no ascorbic acid, but marrow is relatively rich in this vitamin. Quite a bit of this vitamin is oxidized during the deboning operation, but Field (1) estimated there were two to three mg of ascorbic acid per 100 g meat on a fresh weight basis. However, he also stated that this amount is dependent upon the freshness of the bones used for mechanical deboning, and the amount of destruction (of ascorbic acid) which takes place during the deboning process.

#### Fat Content

In addition to ascorbic acid, marrow also contributes a fair amount of lipid components in the form of polyunsaturated fatty acids to the mechanically processed meat product. These components are responsible for the large increase in fat content of the meat (2). Field and Riley (38) reported that the femur marrow of two to three month old calves contained 33.7 percent fat. However, they also approximated the total fat content of the femur marrow in 48 to 96 month old cattle to be 91.8 percent. Gong and Arnold (39) stated that the marrow from long bones had a much higher concentration of fat than other bones in the carcass. Moerck and Ball (40) and Mello, Field, Froenza, and Kunsman (41) also confirmed the fact that the bone marrow lipids contained more

unsaturated fatty acids than the subcutaneous or intramuscular fat from the same animals.

This addition of "polyunsaturated" fatty acids is generally considered good; however, it does affect the stability of mechanically processed meat somewhat (13). The unsaturated fatty acids make it more susceptible to oxidation, and therefore, less stable than hand-deboned meat. However, the large decrease in flavor during storage as reported by Dimick, MacNeil, and Grunden (42) for mechanically processed poultry is not as likely to be present in mechanically processed red meats. This is thought to be due largely to the higher percentage of heme pigments found in the red meats.

The total fat content of mechanically processed meat varies due to such things as differences in age of the cow, grade, and anatomical location of the bones (20). Goldstrand (19) and Field (13) reported that mechanically processed meat from beef neck bones was 9.9 to 24.4 percent fat, and 10 to 15 percent fat respectively. In contrast, however, Field (13) reported that mechanically processed meat from beef plates trimmed under commercial conditions was often 40 to 50 percent fat. Analyses performed by the USDA indicated a range of 20 to 50 percent total lipids in mechanically processed meat (11). It should be kept in mind, however, that food products containing mechanically processed meat are limited in the amount of total fat which can be incorporated into the final product (6). It is, therefore, reasonable to assume that the total fat content of those products would remain the same. Thus, the use of mechanically processed meat would not lead to appreciable increases in dietary lipids when substituted for other meat products of a similar fat content (11).

## Iron

Being quite rich in myoglobin, the bone marrow also provides a good source of iron (34). Because iron is an essential constituent of hemoglobin, cytochrome, and other components of respiratory enzyme systems (43), it is an element of great fundamental importance. However a large segment of the population falls short of the recommended dietary allowance for iron. Of all the nutrients, the iron allowance is the most difficult to provide in the diet (35). With the lower caloric requirements of girls and women, it is almost impossible for them to supply their needs even with a good diet selection.

According to the 1965 dietary survey of the United States Department of Agriculture, females between the ages of nine and 54 years of age fell short of the Recommended Dietary Allowance for iron by 30 percent or more. Mayer (44) stated that iron deficiency anemia is probably the most prevalent nutritional disorder among infants and children in the United States. He further reported that one reason for the prevalence of this condition among infants may be due to the fact that the pregnant woman does not ingest enough iron to maintain adequate stores in the fetus.

Field (13) reported that although hand-deboned meat is a good source of dietary iron, mechanically processed meat is an even better source. He found that commercial hand-deboned ground meat contained 2.6 to 3 mg iron per 100 g meat. Mechanically processed meat, on the other hand, contained an average of 4.3 to 6.3 mg per 100 g meat. Therefore, approximately twice as much iron is present in mechanically processed meat as in hand-deboned meat.

Since ground meat products are popular diet choices of the American population, the incorporation of mechanically processed meat in such products may result in an increase in dietary iron intakes. Such an increase is beneficial from a dietary standpoint.

### Protein

The protein content of mechanically processed meat is somewhat different from hand-deboned meat, but this difference can be expected to be slight. The difference is due to the fact that some connective tissue is removed by the mechanical deboner. Field and Riley (17) found hydroxyproline, an indicator of the amount of connective tissue, to be present in lesser amounts in mechanically-deboned lamb breasts than in comparable hand-deboned lamb breasts. Field and Riley (17) also reported that mechanically-deboned lamb breasts contained less glycine and proline than hand-deboned breasts. This further confirmed that some connective tissue, as well as bone, is removed by the deboner (13).

Beef, pork, and lamb bones come from the fabrication room with large amounts of connective tissue attached to them. In addition, the bones also contain 20 to 30 percent collagen (45). Therefore, Field (13) reported,

Even though large amounts of connective tissue are removed during mechanical deboning, deboned meat from fabrication-room bones often contains as much connective tissue as many hand-deboned products (p. 42).

By determining the essential amino acid composition of various mechanically processed meat samples, Field and Chang (46) were able to assess the protein quality of the samples. Their findings revealed

the protein quality of mechanically processed meat to be dependent on the amount of lean meat and collagen left on the bones prior to deboning. The protein quality of mechanically processed meat which contains more lean and less collagen is superior to the mechanically processed meat which contains less lean and more collagen. This confirmed Field's earlier findings (13). He reported that the highest protein percentages were in mechanically processed meat samples from bones which had the highest percentages of meat left on them prior to deboning. Bones which had the least meat adhering to them yielded mechanically-deboned meat with the least protein and the most fat.

Field (1) also noted that there was an inverse relationship between the percentages of protein and calcium present in mechanically processed meat. Increasing the amount of meat on the bone increased the percentage of protein present, but decreased the percentage of calcium and ash. Just the opposite effect was seen when the amount of meat on the bones was decreased. However, diluting the bone with more meat did not reduce the weight of calcium or ash extracted from the bone. It merely decreased the percentages because more meat was present.

When whole carcasses or carcass parts are mechanically processed, the composition of the resulting product is very similar to the composition of hand-deboned meat from the same carcass (1). Field, Riley, and Corbridge (18) hand-deboned one side of mutton carcasses and mechanically processed the other side of the same carcass. They reported that there was no significant differences in fat, protein, or moisture content between hand-deboned and machine-deboned meat. Field and Riley (17) reported similar results with whole beef carcasses and lamb breasts. Calcium content of mechanically processed meat from

whole carcasses or carcass parts at 0.10 to 0.30 percent was much lower than it was for bones (1).

## CHAPTER III

### METHODS AND PROCEDURES

In accordance with the stated purpose of this study, the researcher analyzed the chemical composition of mechanically processed beef to determine its nutritive content. The design of the study, the meat sample selected, and the methods of analysis are contained in this chapter.

#### Type of Research

The hypotheses were tested by means of the experimental method of research design. Best (8) justifies the use of this method by stating that experimentation is the most sophisticated, exacting, and powerful method for discovering and developing an organized body of knowledge. As defined by Compton and Hall (47), the experimental method is the application of logic or reason to observations made in a completely controlled situation where only one variable is permitted free play. Such a variable is denoted as the independent variable.

In this study, the independent variable is the mechanical processing technique. Two dependent variables are included in the study. These are the nutritive value of mechanically processed beef and the nutritive value of hand-deboned beef (as reported in available literature).

### Meat Sample

Beehive Machinery, Inc., P.O. Box CC, Sandy, Utah, furnished the mechanically processed meat to be used. Variables of age, grade, anatomical location, etc., were not controlled because mechanically processed meat samples typical of those likely to be used for commercial products were desired. However, the meat was to conform to standards specified in the Federal Register, Volume 41, No. 82, page 19762, April 27, 1976, for Class 7, Mechanically Deboned Meat.

### Nutrient Analyses

Upon arrival of the mechanically processed meat, a series of chemical analyses were performed to determine its:

1. mineral content,
2. protein content, and
3. fat content.

The procedures followed in the collection of data are also described.

Mineral Analyses. Mineral Analyses were determined with the aid of the Perkin-Elmer Model 403 and Model 272 Atomic Absorption Spectrophotometers. To obtain a reading of the percentages of minerals present, the meat and standards were first digested. After reconstitution, they were introduced into the spectrophotometer, and the concentration was then multiplied times the dilution factor to arrive at the sample concentration. Appendix A outlines the procedures used and the raw data concerning the mineral analyses.

The above procedure was followed in determining calcium, magnesium, manganese, zinc, iron, chromium, copper, lead, and potassium.

Phosphorus, however, was determined by means of chemical analysis (48). To determine the phosphorus content, a set of standards ranging in concentration from zero to 10 ug/g was first prepared. A mixture of ammonium molybdate, ammonium metavanadate, and concentrated nitric acid was then added to the digested meat samples. The color was allowed to develop for 30 minutes before the samples and standards were read on the Coleman Junior II Spectrophotometer at 440 mu. A standard curve was prepared and the samples were then plotted to determine their concentration. Appendix B shows data related to this determination.

Protein Analysis. Protein analysis of mechanically processed meat was accomplished by means of the Kjeldahl procedure (Oklahoma State University Meat Lab Procedure; outlined in Appendix C). The principle of this method was to convert the various nitrogenous compounds in the meat into ammonia sulfate by boiling samples with concentrated sulfuric acid. The ammonia sulfate was then decomposed upon the addition of NaOH, and the liberated ammonia was collected in an acid of known strength. The resulting solution was then titrated with an acid of known strength and the protein content of the meat was computed. (See Appendix C.)

Fat Analysis. To determine the percent fat present in mechanically processed meat, the fat was first extracted from the sample. A modified version of the ether extraction process described in the AOAC Handbook (48) was used for this purpose. (See Appendix C.) To determine the type and amount of fatty acids present in the samples, a portion of the extracted fat was retained. A modified version of the quantitative

method for the preparation of the extracted fat as described by Mason and Waller (49) was utilized for this analysis. (See Appendix D.)

#### Cleaning the Glassware

In order to obtain accurate results from these tests, it was imperative that the glassware be as clean as possible. This meant it must be free not only of any dust, dirt, or adhering residue, but also of any contaminants or minerals contained in the water in which it was washed. Therefore, only double distilled, deionized water was used throughout the study. The nitric acid used in the mineral analysis was also glass-distilled to remove any impurities which it contained and all glassware was washed with phosphate-free detergent. The glassware was washed and rinsed in accordance with specifications outlined in Handbook for Analytical Quality Control in Water and Wastewater Laboratories (50). Distilled nitric acid was also used in the glass-cleaning procedure. After being thoroughly rinsed, the glassware was transferred to an enclosed drying oven and then stored in a sealed glass cabinet. The samples and reagents were kept tightly covered except when being used. Only plastic or teflon-coated tongs, forceps, tweasers, etc., were used so as to avoid chromium contamination. For the same reason, chrome-plated faucets and other metallic items were also covered with plastic.

## CHAPTER IV

### RESULTS AND DISCUSSION

This chapter includes a discussion of the data regarding the nutritive value of mechanically processed beef. The findings are compared with previously reported data. A comparison was also made between the nutritive content of mechanically processed meat and hand-deboned meat when existing literature made such a comparison possible.

The individual minerals assayed and the corresponding quantities present in mechanically processed meat are shown in Table V. Means, variances (V.), and standard deviations (S.D.) are also shown for each of the 10 minerals determined. For comparison, Table VI lists the approximate quantity of the same minerals contained in hand-deboned beef.

#### Mineral Comparison

As expected, mechanically processed beef was higher in calcium, phosphorus, iron, chromium, and lead than was hand-deboned beef. A very slight elevation in the copper content was noted in mechanically processed beef, but not enough to be considered significant. Magnesium, zinc, and potassium levels, however, were found to be higher in hand-deboned meat. Such an outcome could have been due to incomplete digestion, or the fact that the animals rations were low in these minerals. However, judging from the large quantity of calcium present in the

TABLE V  
MINERAL CONTENT OF MECHANICALLY PROCESSED BEEF (IN UG/GM)

	Magnesium	Manganese	Zinc	Iron	Chromium	Copper	Lead	Potassium	Calcium	Phosphorus
Sample A	30.058	0.683	25.504	70.590	2.742	1.230	1.776	139.359	(1.72%) 17,218.978	(0.68%) 6845.45
Sample B	32.883	0.715	25.497	71.486	2.748	1.144	1.763	141.065	(1.81%) 18,068.702	(0.69%) 6863.64
Sample C	32.344	0.708	25.269	63.171	2.540	0.809	1.516	136.955	(1.78%) 17,750.000	(0.74%) 7420.00
Mean	31.762	0.702	25.423	68.416	2.677	1.061	1.682	139.126	(1.77%) 17,679.227	(0.70%) 7043.030
S.D.	1.5000	0.017	0.134	4.564	0.119	0.222	0.144	2.065	0.046%	0.32%
V.	2.250	0.0003	0.018	20.831	0.014	0.050	0.021	4.264	0.002%	0.001%

TABLE VI

## MINERAL CONTENT OF HAND-DEBONED BEEF (IN UG/GM)

	Magnesium*	Manganese <sup>5</sup>	Zinc <sup>1</sup>	Iron*	Chromium <sup>1</sup>	Copper <sup>2</sup>	Lead <sup>3,4</sup>	Potassium*	Calcium*	Phosphorus*
Ground Beef	170	-	34	27	.57	1.0	.05-.248	2360	(0.01%) 100	(0.156%) 1560

Sources: \*B. K. Watt and A. L. Merrill, Composition of Foods - Raw, Processed, Prepared (1963).

<sup>1</sup>E. W. Murphy, B. W. Willis, and B. K. Watt, "Provisional Tables on the Zinc Content of Foods," Journal of the American Dietetic Association (1975).

<sup>2</sup>H. C. Sherman, Chemistry of Food and Nutrition (1941).

<sup>3</sup>"Health and Safety Aspects of the Use of Mechanically Deboned Meat" (1977).

<sup>4</sup>E. W. Murphy and R. E. Engel, "The Mineral Element Content of Mechanically Deboned Beef and Pork" (1977).

<sup>5</sup>Information Unavailable

samples, it appeared that the processor may have used bones with very little lean meat adhering to them--the net result being a product with a great deal of calcium, and a considerable amount of fat. Because the aforementioned minerals were distributed in the lean muscle tissue of the animal, this could account for the fact that the specified minerals were present to a greater extent in hand-deboned meat than in mechanically processed meat.

The observed calcium values of 1.72 percent also exceeded the proposed USDA maximum calcium standards. Recent calcium analyses of mechanically processed meat by other researchers in the field, however, indicated a mean concentration of 0.5 percent in most samples of red meat, with a few values being somewhat higher (11). In consideration of this average calcium concentration (0.5 percent) for mechanically processed meat, the additional calcium intake due to the ingestion of mechanically processed beef in the form of 2 franks and 2 ounces of bologna would be as follows in Table VII.

Assuming the mechanically processed meat contained an average concentration of 1 percent calcium (the proposed USDA maximum allowance for mechanically deboned meat used for processing) the intake from mechanically processed meat in these products would result in an addition of 300 mg calcium per day.

In view of the fact that many people fall short of the RDA for calcium, mechanically processed meat appears to be a good means of supplementing the diet so as to compensate for that shortage. Assuming the RDA of 800 mg calcium per day was already met by the individual, an addition of 300 mg calcium per day would increase the intake to 1100 mg calcium per day. In view of recent findings in the area of

calcium utilization and retention (52), this would not be considered an excessive amount (11). However, the researcher is in favor of the proposed ruling which requires appropriate labeling so as to inform the consumer that the product contains additional calcium. If this were done, the small percentage of the population which required a low calcium intake for medical purposes could refrain from buying the product. Also, those requiring a high calcium intake due to osteoporosis, or long-term treatment with medications which induced a loss of calcium could be made aware of the availability of the additional calcium.

TABLE VII

PROJECTED CALCIUM INTAKE<sup>1</sup> DUE TO THE INGESTION  
OF MECHANICALLY PROCESSED BEEF PRODUCTS AT A  
CONCENTRATION OF 1 PERCENT CALCIUM

Meat Product	Quantity	Weight gm	MPM, 20% of Weight gm		Calcium mg/gm	Calcium Content of Added MPM (mg)
			Theoretical	Actual*		
Frank	2	120	24	20	5	100
Bologna	2 oz.	60	12	<u>10</u>	5	<u>50</u>
Total 30 gm/day						150 mg/day

\*Based on 17 percent of weight because meat makes up approximately 85 percent of the total ingredients of the meat product.

<sup>1</sup>Projected intake of calcium due to the intake of meat products containing MPM has been calculated on the basis of consumption data. These data are shown in "Health and Safety Aspects of the Use of Mechanically Deboned Meat" (1977).

Source: "Health and Safety Aspects of the Use of Mechanically Deboned Meat" (1977).

Average calcium-phosphorus ratios of the mechanically processed meat as observed by the researcher were 2.5, while Murphy and Engel (21) reported an average ratio of 1.7. This again tends to confirm the researcher's hypothesis that the mechanically processed meat under investigation was composed of a large proportion of bone in relation to lean meat. Soft tissues contain much higher amounts of phosphorus than calcium, but in bones, the proportion of calcium to phosphorus is about 2:1 (35).

### Zinc

Although Tables V and VI show zinc to be higher in hand-deboned meat than in mechanically processed meat, it would be expected that this is not the case if the product was prepared in accordance with government specifications. A study of mechanically processed meat performed by the USDA shows the concentration of zinc to range from 34.17 to 46.80 ug/gm (11). Thus, zinc content of the two kinds of beef were very similar. These findings were also in agreement with the research by Murphy and Engel (21).

### Iron

The iron content of mechanically processed meat was considerably higher than that of hand-deboned meat. Murphy and Engel (21) reported that a direct correlation existed between the calcium and iron content of mechanically processed meat. Therefore, since the mechanically processed meat analyzed for this study was higher in calcium than that which would appear in consumer products, the mean value of 68.416 ug/gm was also probably somewhat higher than that which would be observed in

mechanically processed meat prepared for commercial products. Murphy and Engel (21) reported a mean value of 42.6 ug/g while the USDA reported 54 ug/gm at the 90th percentile iron concentration (11). This was slightly less than twice the value for iron in hand-deboned lean beef.

Since many people do not meet the RDA for iron, mechanically processed meat will be advantageous from a nutritional standpoint. Its incorporation in the average American diet could result in a beneficial increase in dietary iron intake by the United States population.

#### Lead

Murphy and Engel (21) reported a mean lead content of 0.09 ug lead per gram meat when the mechanically processed meat contained a mean calcium level of 0.63 percent. From this, they determined that mechanically processed meat was only slightly higher in lead than its hand-deboned counterpart, and thus presented no significant danger if added to the American diet. United States Department of Agriculture studies reported similar findings (11).

It was also determined that there was a direct relationship between the amounts of calcium and lead in mechanically processed meat. Therefore, the researcher in this study determined that the samples of mechanically processed meat under investigation contained a greater quantity of lead (1.685 ug/gm) than was reported for mechanically processed meat within the proposed calcium levels.

The quantities of lead that produce toxicity are 2000 to 3000 ug per day for adults, and 1000 ug per day for children if exposure continues over several months. Furthermore, approximately one-half these

amounts can produce changes in synthesis of hemoglobin (11). However, the researcher determined that even at the concentration levels found in the mechanically processed meat under investigation, the amount of lead added to the diet would not lead to toxicity in the adult diet. A representative lead intake due to the ingestion of mechanically processed meat at a concentration of 1.685 ug/gm (the mean concentration determined in this study) is shown in Table VIII.

TABLE VIII  
PROJECTED LEAD INTAKE<sup>1</sup> DUE TO THE INGESTION OF  
MECHANICALLY PROCESSED BEEF PRODUCTS AT A  
CONCENTRATION OF 1.685 UG LEAD/GM MEAT

Meat Product	Quantity	Wt. gm	MPM, 20% of Weight gm		Lead mg/gm	Lead Content of Added MPM (mg)
			Theoretical	Actual*		
Frank	2	120	24	20	.001685	.0337
Bologna	2 oz	60	12	<u>10</u>	.001685	<u>.01685</u>
Total 30 gm/day						.05055 mg/day or 50.55 ug/day

\*Based on 17 percent of weight because meat makes up approximately 85 percent of the total ingredients of the meat product.

<sup>1</sup>Projected intake of lead due to the intake of meat products containing MPM has been calculated on the basis of consumption data. These data are shown in "Health and Safety Aspects of the Use of Mechanically Deboned Meat" (1977).

The tolerable lead intake for adults, as established by the World Health Organization, is 429 ug lead per day or 7 ug lead per kg body weight per day (11). Therefore, neither the 50 ug lead which would be added to the adult diet, nor the amount added to the child's diet (approximately one-half as much since his consumption would probably be cut in half) should raise the concentration to a toxic level. The concentration of lead (.05 ug/gm) found in mechanically processed meat containing the proposed amount of calcium was considered insignificant (11) and should not produce a noticeable change in one's lead intake.

#### Potassium

The potassium content of the mechanically processed meat was considerably lower than the level determined by Watt and Merrill (23) in hand-deboned beef. Because of the large percentage of bone material in the mechanically processed meat, it is believed the observed reading may be largely a measure of the potassium content of the bone and its marrow.

#### Lipid Content

The mean total lipid content of the mechanically processed meat under investigation was 33.32 percent, with individual samples ranging from 25.44 percent to 49.06 percent. Since the fifteen samples analyzed were obtained from the same batch of meat, the possibility exists that there may have been pockets of fat distributed unevenly within the bulk sample. The mean lipid content was actually only slightly greater than that of regular ground beef which may contain as much as 30 percent fat (53). Watt and Merrill (23), however, established the mean

total fat content of ground beef to be 21.2 percent. Kunsman and Field (20) also reported that mechanically processed meat from beef has a lipid spectrum similar to that of ground beef. However, the mechanically processed meat analyzed for their study contained considerably less fat (8.8 percent) than was determined by the researcher in this project. Differences in lipid content reflect differences in age, grade, anatomical location, amount of meat and fat attached to the bone, size of bone, etc.

Tables IX through XII contain summarized results of the fat determination. By means of gas chromatographic analysis, the researcher was able to identify and quantitate the various fatty acids present in the lipid portion of the mechanically processed beef (see Table X). Table XI portrays the percent saturated fatty acid versus the percent unsaturated fatty acid present. As can be seen, the total lipid content was low in polyunsaturated fatty acids. Linoleic and linolenic acid comprised only 2.1 percent of the total lipid spectrum. Arachidonic, if present, was in such small quantities that it was undetectable by the gas chromatograph. The total polyunsaturated fatty acid content of hand-deboned ground beef as determined by Anderson, Kinsella, and Watt (54) was 0.9 percent. Therefore, mechanically processed meat is significantly higher in polyunsaturated fatty acids than is hand-deboned meat. This was an expected outcome of the study because the bone marrow lipids found in mechanically processed meat contain more polyunsaturated fatty acids than the subcutaneous or intramuscular fat (40, 41).

Mean total saturated fatty acid content of the mechanically processed meat was 18.95 percent while unsaturated fatty acids comprised

TABLE IX  
FAT DETERMINATION OF MECHANICALLY PROCESSED BEEF

Tube No.	(Dried) Tube Wt.	Weight of Meat and Tube	Wet Sample Weight	Weight of Meat and Tube After Drying	Moisture (Difference in Weight)	Percent* Moisture	Tube and Meat Weight After Extraction and Drying	Difference in Dry Wt. Before and After Extraction	Percent <sup>1</sup> Fat
10	11.7044	13.8938	2.1894	13.0601	0.8337	38.08	12.2949	0.7652	34.95
60	12.5526	14.7886	2.2360	13.8790	0.9096	40.68	13.0965	0.7825	35.00
80	12.2395	14.4026	2.1631	13.4821	0.9205	42.55	12.6479	0.8342	38.57
130	12.1472	14.2863	2.1391	13.4063	0.8800	41.14	12.8149	0.5914	27.65
140	12.4872	14.5406	2.0534	13.7544	0.7862	38.29	13.1090	0.6454	31.43
4	12.3749	14.4504	2.0755	13.5425	0.9079	43.74	13.0607	0.4818	23.21
180	12.3737	14.5203	2.1466	13.5708	0.9495	44.23	12.7184	0.8524	39.71
C9	12.7700	14.7782	2.0082	13.8758	0.9024	44.94	13.3346	0.5412	26.95
190	12.4323	14.5763	2.1440	13.6322	0.9441	42.09	13.0867	0.5455	25.44
220	12.1055	14.3248	2.2193	13.3973	0.9275	41.79	12.7162	0.6811	30.69
250	12.2037	14.4966	2.2929	13.5741	0.9225	40.23	12.6453	0.9288	40.51
260	12.0394	14.0412	2.0018	13.1753	0.8659	43.26	12.1933	0.9820	49.06
1030	12.2608	14.5478	2.2870	13.6171	0.9307	40.70	12.9642	0.6529	28.55
6030	12.2585	14.4477	2.1892	13.5043	0.9434	43.09	12.7707	0.7336	33.51
4050	12.7335	14.8803	2.1468	13.9996	0.8807	41.02	13.2585	0.7411	34.52
						$\Sigma = 625.83$			
						$\bar{X} = 41.72$			
								$\Sigma = 499.75$	
								$\bar{X} = 33.32$	

\*Percent moisture equals moisture ÷ weight of sample x 100

<sup>1</sup>Percent fat equals difference in dry weight before and after extraction ÷ weight of sample x 100

TABLE X

## FATTY ACID ANALYSIS OF MECHANICALLY PROCESSED BEEF

Sample Number	Total Fat (Percent)	Percent Fatty Acids								Moisture (Percent)
		Lauric	Myristic	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic	
10	34.95	1.96	3.51	29.83	3.99	16.69	41.47	1.45	1.09	38.08
60	35.00	.68	2.99	32.76	4.43	19.64	38.01	.75	.74	40.68
80	38.57	.93	3.34	29.02	4.30	17.11	42.81	1.37	1.12	42.55
130	27.65	1.26	3.30	29.71	3.10	18.42	41.99	1.23	.98	41.14
140	31.43	2.14	3.86	35.46	3.60	22.42	30.74	.86	.92	38.29
4	23.21	2.13	3.43	28.65	4.62	20.42	39.19	1.00	.56	43.74
180	39.71	1.03	3.31	32.33	.77	20.45	39.70	1.45	.96	44.23
C9	26.95	2.31	3.43	30.40	3.63	21.59	36.71	.97	.97	44.94
190	25.44	2.87	3.67	35.46	3.42	21.94	30.71	.94	.99	42.09
220	30.69	.79	3.72	31.10	3.24	23.81	35.09	1.29	.96	41.79
250	40.51	.65	3.17	33.37	3.98	21.73	35.35	.85	.91	40.23
260	49.06	1.22	3.54	31.27	4.04	20.38	37.75	.85	.97	43.26
1030	28.55	4.37	3.94	29.47	3.65	22.78	33.84	1.00	.97	40.70
6030	33.51	.52	3.12	28.74	4.25	18.49	41.49	1.88	1.51	43.09
4050	34.52	.78	3.28	33.14	3.59	21.26	35.99	1.00	.96	41.02
$\Sigma$	499.75	23.64	51.61	470.71	54.61	307.13	560.84	16.89	14.61	625.83
Mean	33.32	1.58	3.44	31.38	3.64	20.48	37.39	1.13	0.97	41.72
gm/100 gm	33.32	.53	1.15	10.45	1.21	6.82	12.46	.38	.32	41.72

TABLE XI

MECHANICALLY PROCESSED BEEF: PERCENT SATURATED FATTY ACIDS  
VERSUS PERCENT UNSATURATED FATTY ACIDS

Sample Number	Percent Saturated Fatty Acids				Total* Saturated Fatty Acids	Percent Unsaturated Fatty Acids				Total* Unsaturated Fatty Acids
	C <sup>o</sup> <sub>12</sub> Lauric	C <sup>o</sup> <sub>14</sub> Myristic	C <sup>o</sup> <sub>16</sub> Palmitic	C <sup>o</sup> <sub>18</sub> Stearic		C <sup>l</sup> <sub>16</sub> Palmitoleic	C <sup>l</sup> <sub>18</sub> Oleic	C <sup>ll</sup> <sub>18</sub> Linoleic	C <sup>lll</sup> <sub>18</sub> Linolenic	
10	1.96	3.51	29.83	16.69	51.99	3.99	41.47	1.45	1.09	48.00
60	.68	2.99	32.76	19.64	56.07	4.43	38.01	.75	.74	43.93
80	.93	3.34	29.02	17.11	50.40	4.30	42.81	1.37	1.12	49.60
130	1.26	3.30	29.71	18.42	52.69	3.10	41.99	1.23	.98	47.30
140	2.14	3.86	35.46	22.42	63.88	3.60	30.74	.86	.92	36.12
4	2.13	3.43	28.65	20.42	54.63	4.62	39.19	1.00	.56	45.37
180	1.03	3.31	32.33	20.45	57.12	.77	39.70	1.45	.96	42.88
C9	2.31	3.43	30.40	21.59	57.73	3.63	36.71	.97	.97	42.28
190	2.87	3.67	35.46	21.94	63.94	3.42	30.71	.94	.99	36.06
220	.79	3.72	31.10	23.81	59.42	3.24	35.09	1.29	.96	40.58
250	.65	3.17	33.37	21.73	58.92	3.98	35.35	.85	.91	41.09
260	1.22	3.54	31.27	20.38	56.41	4.04	37.75	.85	.97	43.61
1030	4.37	3.94	29.47	22.78	60.56	3.65	33.84	1.00	.97	39.46
6030	.52	3.12	28.74	18.49	50.87	4.25	41.49	1.88	1.51	49.13
4050	.78	3.28	33.14	21.26	58.46	3.59	35.99	1.00	.96	41.54
Σ	23.64	51.61	470.71	307.13	853.09	54.61	560.84	16.89	14.61	646.95
Mean	1.58	3.44	31.38	20.48	56.87	3.64	37.39	1.13	.97	43.13
V.	1.13	.07	5.22	4.31	17.99	.8237	14.74	.10	.04	17.96
S.D.	1.06	.26	2.28	2.08	4.24	.9076	3.84	.31	.20	4.24

\*As a percent of the total fat present

the remaining 14.37 percent; thus totaling the 33.32 percent fat present. Table XII shows a comparison of the fatty acid content of the two types of meat in question. Due to the greater percentage of unsaturated fatty acids in mechanically processed meat, its storage life may be noticeably reduced.

TABLE XII  
PERCENT FAT IN HAND-DEBONED BEEF VERSUS PERCENT  
FAT IN MECHANICALLY PROCESSED BEEF

Meat Product	Total Fat %	Percent Saturated Fat**	Percent Unsaturated Fat**
Hand-Deboned Beef*	21.20	10.00	11.20
Mechanically Processed Beef	33.32	18.95	14.37

\*Source: B. K. Watt and A. L. Merrill, Composition of Foods - Raw, Processed, Prepared (1963).

\*\*As a percent of the total fat present

#### Moisture Content

Moisture content of the mechanically-deboned meat ranged from 38.08 to 44.94 percent with a mean of 41.72 percent. These findings were in agreement with those of Field (13) who reported a range of 30 to 45 percent moisture in mechanically processed meat obtained from beef plates. This is in contrast to the 60.2 percent moisture content of ground beef (23).

### Protein Content

The mean protein content of mechanically processed meat as determined by the Kjeldahl procedure was 13.55 percent. (See Appendix C.) This was in agreement with the findings of Murphy and Engel (21) who reported an average of 13.5 percent protein. Mechanically processed meat was lower in protein than hand-deboned ground beef which was determined to have a mean value of 17.9 percent protein (23). This was expected, since some of the connective tissue is also discarded along with the bone residue.

## CHAPTER V

### SUMMARY AND RECOMMENDATIONS

The purpose of this work was to determine the protein, mineral, and fat content of mechanically processed beef. In so doing, the researcher wished also to compare its nutritive content with reported values for hand-deboned beef.

A variety of methods were used. Mineral analyses were determined by the atomic absorption spectrophotometer and a colorimetric assay procedure.

An ether extraction was used to determine the fat content of mechanically processed beef and the gas chromatograph was utilized to identify the various fatty acid components of the fat. To ascertain the amount of protein in mechanically processed meat, the Kjeldahl method of protein analysis was used. Literature referring to the nutritive quality of hand-deboned beef was used to establish a comparison between the two types of meat.

The results were presented in chart form. The mean values were compared with values reported by other researchers as well as with values reported for a similar cut of hand-deboned beef. Minerals determined were calcium, phosphorus, magnesium, manganese, zinc, iron, chromium, copper, lead, and potassium.

In general, it was determined that mechanically processed meat is similar to hand-deboned meat in many respects. Although higher

in calcium than hand-deboned beef, this is not considered detrimental from a nutritional standpoint. In fact, it may be considered an asset to those not meeting the RDA for calcium.

The increased mineral content, which may also prove beneficial to many, was not so highly concentrated in any one nutrient as to produce toxicity. Since products containing mechanically processed meat would be limited in total fat content, it is assumed that the use of mechanically processed meat would not lead to an appreciable increase in dietary fat intake. However, the higher unsaturated fat content of mechanically processed meat could result in accelerated deterioration during storage.

#### Recommendations for Further Study

Because mechanically processed red meat is a relatively new procedure in the food processing industry, there is still a lot to be learned about the practical application and use of the product.

Due to the injunction imposed upon the manufacture of the product at the time of this study, the author was able to receive only one shipment of mechanically processed beef for research purposes. It is therefore recommended that the study be repeated when production begins again so that correlations and variances between the various nutrient components could be established among a number of different samples.

A comparison of the nutrient values of cooked mechanically processed meat versus raw processed meat would also be of value. In so doing, it would also be possible to determine the effect that different cooking methods and/or temperatures had on the nutrient content of the meat.

Many different rations and methods of feeding are available to the rancher today. Therefore, it might also be interesting to conduct a long-term study to see if either of these factors greatly affected the quality of the resulting meat fraction. Because the soil differs in mineral content between regions of the country, it is also recommended that studies be done to determine if there is enough variation between geographic areas to affect the nutrient content of the mechanically processed meat. Studies of variances in grades as well as breeds of animals would also add more to our knowledge in this area.

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## APPENDIX A

### DATA RELATED TO MINERAL ANALYSES

## Mineral Analyses

### Digestion\*

Fifteen samples of mechanically processed meat, each weighing approximately two grams were covered with 60 ml concentrated 3:1 70 percent  $\text{HNO}_3$ : 70 percent  $\text{HClO}_4$  in 200 ml beakers. Tight-fitting coverslips were then placed on each beaker, and they were allowed to sit overnight. After replacing the coverslips with raised ones, complete oxidation of the organic matter was obtained by heating the samples. To insure even heating, the beakers were placed in an electric skillet containing mineral oil. A thermometer was placed in the oil to monitor the temperature, and the digestion temperature was gradually raised to approximately 160° C.

The samples were allowed to evaporate to approximately two ml. This usually required 10 to 15 hours. If at this point, any of the samples were not clear and colorless, five ml of 30 percent  $\text{H}_2\text{O}_2$  was added to each sample, and heating was continued. If still not colorless, the procedure was again repeated.

### Reconstitution

After the samples became clear and colorless, five ml  $\text{HNO}_3$  was added to the beakers and they were evaporated to near dryness (approximately one ml). The sides of the beakers were then rinsed several times with distilled water, and they were again evaporated to approximately

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\*This procedure is a modified version of the one presented by Knight (55).

one to two ml. This rinsing process was repeated three times before the beakers were removed from the heat and each sample transferred to a separate 10 ml volumetric flask. The samples were then allowed to cool before being brought to volume with distilled water. These 10 ml samples were then filtered into plastic sample bottles where they were kept under refrigeration until the mineral content was determined with the aid of an atomic absorption spectrophotometer.

At this time, five of the 10 ml samples (excluding the blanks) were randomly selected. They were combined in a 50 ml container and designated as Sample A. The procedure was repeated a second and a third time to generate Samples B and C respectively. The five blanks were also combined.

#### Reading the Samples

Standard solutions, in ug/g, for each mineral to be assayed were prepared to bracket the expected concentrations of the mechanically processed meat samples. The standards and samples were then read on the Perkin Elmer Atomic Absorption Spectrophotometer using the procedure outlined in the Perkin Elmer Operating Manual (57).

The Perkin Elmer Model 403 was used to analyze the minerals in higher concentration, while the Perkin Elmer Model 272, which is more sensitive, was required for the analysis of those minerals present only in very small concentration. The standards' readings were used to plot standard curves and the sample concentrations were then read from the standard curves. The machine did this automatically, thus reducing any margin of error. The concentration of a mineral in the mechanically processed meat was calculated as follows:

concentration (as read from Perkin-Elmer) x  
dilution factor = sample value (ug/g)

Raw data showing the amount of meat used in the 15 samples for the digestion procedure, the result of the random selection which yielded Samples A, B, and C, and the calculation of the dilution factors for each sample follow.

## MEAT DIGESTION DATA

Beaker Number	Beaker Weight	Beaker and Meat Weight	Meat Weight
122	74.2277	76.2334	2.0057
2	76.9992	79.0270	2.0278
3	89.0647	91.0316	1.9669
102	54.2680	56.2476	1.9796
54	91.8475	94.0471	2.1996
55	77.1460	79.1481	2.0021
5	77.9495	80.2528	2.3033
66	94.9854	97.3548	2.3694
7	77.0341	79.1440	2.1099
6	77.4525	79.7394	2.2869
63	90.7856	92.7842	1.9986
61	90.8901	93.1703	2.2802
1	76.3548	78.4802	2.1254
11	76.2172	78.3430	2.1258
12*	76.2075	80.7661	2.5586

\*Had to be discarded due to spillage

Five blanks were also prepared

GENERATION OF SAMPLES A, B, AND C AS A  
RESULT OF RANDOM SELECTION

Sample A = Numbers: 61

5

6

7

63

---

in 50 ml solution

Sample B = Numbers: 66

2

3

55

1

---

in 50 ml solution

Sample C = Numbers: 102

54

11

122

---

in 42 ml solution

Blank = Numbers: 51

401

16

402

50

---

in 50 ml solution

## CALCULATION OF DILUTIONS:

Sample A = Numbers: 61 -- 2.2802 gm meat  
                           5 -- 2.3033 gm meat  
                           6 -- 2.2869 gm meat  
                           7 -- 2.1099 gm meat  
                           63 -- 1.9986 gm meat  
                                   10.9789 gm meat / 50 ml solution

Sample B = Numbers: 66 -- 2.3694 gm meat  
                           2 -- 2.0278 gm meat  
                           3 -- 1.9669 gm meat  
                           55 -- 2.0021 gm meat  
                           1 -- 2.1254 gm meat  
                                   10.4916 gm meat / 50 ml solution

Sample C = Numbers: 102 -- 1.9796 gm meat  
                           54 -- 2.1996 gm meat  
                           11 -- 2.1258 gm meat  
                           122 -- 2.0057 gm meat  
                                   8.3107 gm meat / 42 ml solution

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Sample A Dilution Factor equals:

$$50 \text{ ml} \div 10.9789 = 4.5542$$

Sample B Dilution Factor equals:

$$50 \text{ ml} \div 10.4916 = 4.7657$$

Sample C Dilution Factor equals:

$$42 \text{ ml} \div 8.3107 = 5.0537$$

## APPENDIX B

### DATA RELATED TO PHOSPHORUS DETERMINATION

## PHOSPHORUS DETERMINATION

## Sample A determination:

1. Had 10.9789 gm meat / 50 ml solution
2. Took 0.5 ml of #1 and diluted to 10 ml
3. Took 0.5 ml of #2 and added 3.5 ml distilled  $H_2O$  + 1 ml  $HNO_3$ -ammonium molybdate, ammonium metavanadate to equal 5 ml.

## Calculations:

1.  $10.9787 \div 50 = 0.2196$  gm meat / ml
2.  $.2196 \times 0.5 = 0.1098$  gm meat / 10 ml  
 $.1098 \div 10 = 0.01098$  gm meat / ml
3.  $0.5 \times .01098 = 0.00549$  gm meat / 5 ml  
 $.00549 \div 5 = 0.001098$  gm meat / ml

Therefore, 1 ml solution contained 0.0011 gm meat. From the graph, the researcher determined that the sample contained 7.53 ug phosphorus / ml solution

$$7.53 \div 0.0011 = 6845.45 \text{ ug phosphorus / gm meat}$$

## Sample B determination:

1. Had 10.4916 gm meat / 50 ml solution
2. Took 0.5 ml of #1 and diluted to 10 ml
3. Took 0.5 ml of #2 and added 3.5 ml distilled  $H_2O$  + 1 ml  $HNO_3$ -ammonium molybdate, ammonium metavanadate to equal 5 ml.

## Calculations:

1.  $10.4916 \div 50 = 0.2099 \text{ gm meat / ml}$
2.  $.2099 \times 0.5 = 0.10495 \text{ gm meat / 10 ml}$   
 $.10495 \div 10 = 0.0105 \text{ gm meat / ml}$
3.  $0.5 \times .0105 = 0.00525 \text{ gm meat / 5 ml}$   
 $.00525 \div 5 = 0.00105 \text{ gm meat / ml}$

Therefore, 1 ml solution contained 0.0011 gm meat. From the graph, the researcher determined that the sample contained 7.53 ug phosphorus / ml solution

$$7.53 \div 0.0011 = 6863.64 \text{ ug / gm meat}$$

## Sample C determination:

1. Had 8.3107 gm meat / 42 ml solution
2. Took 0.5 ml of #1 and diluted to 10 ml
3. Took 0.5 ml of #2 and added 3.5 ml distilled H<sub>2</sub>O + 1 ml HNO<sub>3</sub>-ammonium molybdate, ammonium metavanadate to equal 5 ml.

## Calculations:

1.  $8.3107 \div 42 = 0.1930 \text{ gm meat / ml}$
2.  $.1930 \times 0.5 = 0.0965 \text{ gm meat / 10 ml}$   
 $.0965 \div 10 = 0.00965 \text{ gm meat / ml}$
3.  $0.5 \times .00965 = 0.004825 \text{ gm meat / 5 ml}$   
 $.004825 \div 5 = 0.00097 \text{ gm meat / ml}$

Therefore, 1 ml solution contained 0.0010 gm meat. From the graph, the researcher determined that the sample contained 7.42 ug phosphorus / ml solution

$$7.42 \div 0.0010 = 7420 \text{ ug / gm meat}$$

## APPENDIX C

### DATA RELATED TO PROTEIN DETERMINATION

## KJELDAHL METHOD

Fifteen samples of mechanically processed meat, each weighing approximately one gram, along with 25 ml concentrated  $H_2SO_4$ , approximately five granules selenium, and one kelpak containing potassium sulfate, copper sulfate, and pumice were added to 15 Kjeldahl flasks. Five blanks were also prepared. These were boiled until the mixture turned light green and then for an hour longer (total time equaled approximately  $2\frac{1}{2}$  hours). After oxidation was complete, and the samples were allowed to cool, 400 ml distilled water was added to each flask. In addition, 75 ml concentrated NaOH was added to neutralize the sulfuric acid, and approximately five pieces of zinc were added to prevent bumping.

This mixture was then distilled into a distilling flask containing 50 ml boric acid. After approximately 300 ml were collected, the mixture was titrated with 0.1253 N standard sulfuric acid. The total percent protein present in each sample was then calculated. Since exactly one gram samples of meat were not used in the analysis, the volume of sulfuric acid used to titrate the boric acid mixture was corrected to correspond to the weight of the sample. This was done in the following manner:

mls of sulfuric acid used to titrate sample minus  
mls of sulfuric acid used to titrate blank equals

corrected volume

After arriving at the corrected volume, the following formula was used to calculate the percent protein contained in each sample:

$$\frac{\text{corrected volume}}{\text{sample weight}} \times 1.0964 = \text{percent protein}$$

## PROTEIN DETERMINATION DATA

<u>Sample Number</u>	<u>Weight of Sample</u>	<u>ml of sulfuric acid required to titrate</u>
8029	.9998	12.50
8030	1.0001	12.65
8031	1.0000	12.75
8032	1.0000	12.85
8033	1.0000	12.70
8058	.9997	13.00
8059	.9997	12.05
8060	1.0000	12.20
8063	.9987	12.50
8064	1.0000	12.60
8065	1.0003	12.60
16	1.0004	12.70
19	.9996	12.40
20	1.0000	12.65
21	1.0000	12.00
Blanks		
18		.15
5-17		.10
26		.15
27		.225
Blk		<u>.10</u>
		.725
		Mean = .145

## PROTEIN CALCULATIONS

Mls of sulfuric acid used to titrate sample minus  
 Mls of sulfuric acid used to titrate blank equals

Corrected Volume

$\frac{\text{Corrected volume}}{\text{Sample weight}} \times 1.0964 = \text{percent protein}$

<u>Sample Number</u>	<u>Corrected Volume</u>	<u>Percent Protein</u>
8029	12.355	13.5487
8030	12.505	13.7091
8031	12.605	13.8201
8032	12.705	13.3238
8033	12.555	13.7653
8058	12.855	14.0985
8059	11.905	13.0566
8060	12.055	13.2183
8063	12.355	13.5637
8064	12.455	13.6557
8065	12.455	13.6516
16	12.555	13.7597
19	12.255	13.4418
20	12.505	13.7105
21	11.855	<u>12.9978</u>
		203.3212
		mean = 13.5547

## APPENDIX D

### DATA RELATED TO FAT ANALYSIS

## FAT ANALYSIS PROCEDURE

Ether Extraction

Fifteen mechanically processed samples, each weighing approximately 2 grams, were placed in fat extraction tubes and accurately weighed. The samples were held in a drying oven for 6 hours at a temperature of 102-109° C. After allowing them to cool in a desiccator, they were again weighed with the loss in weight recorded as moisture. The samples were extracted overnight with diethyl ether as outlined in the AOAC Handbook (48), redried, and weighed again. Loss in weight was divided by the sample weight and multiplied times 100 to determine the percent fat present.

Fatty Acid Analysis

Approximately 20 mg of the extracted fat was accurately weighed into 15 stoppered test tubes. Reagents were added in the following order: 4 ml sodium-dried benzene, 0.04 ml 2,2-dimethoxypropane, and 0.5 ml of metanolic hydrochloric acid. The reaction mixture was allowed to stand overnight at 22° C. to ensure complete transesterification. Afterwards, the mixture was evaporated to dryness so as to remove the benzene, acetone, HCl, and MeOH. This was accomplished by bubbling gaseous nitrogen through the mixture while blowing hot air across the top of the test tube. The sample was then injected into the Perkin-Elmer 990 gas chromatograph.

As the mixture passed through the instrument, the shorter-chain fatty acids proceeded through the column first and were recorded on a recorder which was hooked to the chromatograph. The longer chain

fatty acids followed in sequence and were likewise recorded. After each sample passed through the instrument (which required approximately 1 hour per sample), the area of the resulting peaks (which were recorded on the accompanying chart) were calculated to determine the exact amount of each fatty acid present. (The results are shown in Tables IX-XII.)

VITA<sup>2</sup>

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