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THE EFFECT OF MECHANICAL TREATMENT OF MEAT PIECES ON SENSORY PARAMETERS OF SECTIONED AND FORMED PROCESSED MEATS

By

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ABSTRACT

THE EFFECT OF MECHANICAL TREATMENT OF MEAT PIECES ON SENSORY PARAMETERS OF SECTIONED AND FORMED PROCESSED MEATS

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A study was designed and conducted to determine the effects of tumbling time (60, 120 and 180 minutes); pressure during tumbling (vacuum and non vacuum); condition of the meat (fresh and frozen and thawed meat); and brine injection level (16% and 32%) on the nature of the exudate after tumbling and the quality parameters of sectioned and formed hams.

Results indicated that protein extraction from frozen meat was faster than that from fresh meat with tumbling time. Fat was extracted rapidly after a short period of tumbling, and the use of vacuum during tumbling did not affect protein and fat extraction. Longer tumbling periods and absence of vacuum during tumbling increased lipid oxidation, with the effect being more evident with frozen meat.

After brine pumping salt and nitrite were retained better by fresh meat than frozen meat. Frozen meat tended to absorb much of the cure during tumbling.

The use of vacuum did not contribute to myosin extraction when the meat was tumbled for 60 minutes. However, the use of vacuum resulted in hams with good color distribution and better tenderness and texture characteristics than those tumbled without vacuum.

No differences in yields, calculated according to Federal regualtions, were evident in hams from fresh and frozen meat, indicating that frozen meat is quite suitable for this type of processing.

Nitric oxide pigment content in hams was adversely affected by vacuum during tumbling. However, color intensity of the hams was not different.

Microscopic study showed a common pattern of increased fiber disrupture in the tissue with tumbling time and in a single muscle chunk going from the interior part to the peripheral part. Fibers from frozen meat showed more damage after tumbling than those from fresh meat. The use of vacuum during tumbling eliminated presence of air bubbles in the exudate.

There were some discrepancies in the direction of the effects of the treatments on binding strength evaluated by the Instron and by taste panel. However, both methods indicated that hams pumped 16% bound significantly better than those pumped 32%.

The use of vacuum during tumbling improved tenderness of hams but not color distribution.

Durante los días gastados escribiendo este trabajo han venido recuerdos y vivencias a mi mente con desusual claridad. He recordado mi infancia y los niños pobres de la tierra donde nací. Aquellos niños de piel oscura de sol, salada de sudor, quemada de frío y salpicada de polvo de los terrosos callejones donde viven y juegan. Aquellos niños de mirar desconfiado, de actitudes candorosas, de cuerpos humildes pero resistentes, de lenguaje limitado pero de profundos y nobles sentimientos en sus interiores. He soñado que algún día todos ellos tendrán la fortuna y oportunidad que yo he tenido en la vida para alcanzar educación superior. Para algunos vendrá pronto; para la mayoría restante, aquellos niños que llevarán su pureza y humildad junto a sus vidas pobres, yo les dedico esta tesis.

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INTRODUCTION

Ancient processing of meat products evolved as an art and only in recent history have scientific principles and advanced technologies been applied in meat processing. Today approximately one out of seven pounds of meat produced in most of the developed countries around the world is consumed as sausage or other processed meat items. Since meat and meat products play a key role in the diets of most cultures by providing high quality proteins, minerals and vitamins and a high satiety value to consumers, the demand for these foods will no doubt remain high.

Although the origin of meat processing has been lost in history, it most likely began when primitive man first discovered that salt is an effective preservative and that cooking prolongs the keeping quality of fresh meat. Today processed meats are highly regarded for the convenience and variety they provide to the meat portion of the diet. Moreover, increasing consumer demand for leaner meat, milder flavor, tender texture and low levels of additives in cured meats has encouraged the industry to experiment with new processing developments.

Recently developed techniques in the production of sectioned and formed meat products allow the retention of

the structural integrity of the original muscle source and result in a greater uniformity than in the original product. Such techniques have become widely used in the meat industry in several European countries and in the United States.

Although these processes are considered to be innovative ones, they actually are adapted applications of ancient principles. They attempt to form a stable heat set protein gel which will effectively bind legal limits of fat and water in an attractive meat product packed so as to maintain wholesomeness, appeal and palatability for a maximum length of time.

Two of the most popular techniques used in the production of sectioned and formed meats are massaging and tumbling. In both cases brine-injected muscle chunks are placed in massagers or tumblers and subjected to various mechanical treatments. Mechanical work is then imparted to the chunks of meat through a process of mixing, churning and pounding in such a manner that the pieces of muscle become soft and pliable and develop a creamy, tacky exudate on their surfaces in the form of a protein coat. The protein coat is then heat-coagulated by cooking to form a binding matrix between muscle chunks which allows the product to possess the look of "intact" muscle foods, such as roast or hams.

The purpose of massaging and tumbling meat is to ensure a quality finished product and to obtain the following objectives: to maximize yields, impose color and binding, reduce

cooking time and loss, control added substances and reduce inventory. The resultant uniformity of the brine distribution, the shortened curing time and the saved pickle are equally important factors to consider in using these two processsing techniques.

This study was designed to assess the mechanical effect of tumbling meat pieces on the nature of the exudate and on texture, cure distribution and acceptability parameters of sectioned and formed boneless hams. Three specific objectives were emphasized (1) the determination of the optimum tumbling sequence of meat pieces for optimum bind, texture and cure distribution characteristics, (the effect of vacuum during the tumbling operation is also assessed at this point); (2) the determination of the effect of the nature of the meat source, (e.g. fresh hams versus frozen and thawed hams) on bind, texture and cure distribution characteristics; and (3) the determination of the effect of the pickle cure level on the acceptance characteristics of the final product.

LITERATURE REVIEW

The Protein System in Pork Muscle

Muscle proteins, as they are organized and distributed within the muscle, have traditionally been classified into two main groups: extracellular and intracellular proteins. The former occur outside the sarcolemmal membrane and the latter are contained inside that membrane (Asghar and Pearson, 1980).

A. Extracellular components: The connective tissue and the proteins of the interstitial space constitute the extracellular components. Morphologically, connective tissue comprises three distinct components.

   1. Fibrous proteins: The major fibrous proteins in the extracellular spaces include collagen, elastin and reticulin (Forrest et al., 1975).
   2. Ground substance: The ground substance occupies the extracellular space of the connective tissue and is a viscous fluid derived from the plasma. It is composed of globular mucoprotein (protein associated with mucopolysaccharides), tropocollagen and tropoelastin (Asghar and Pearson, 1980).
   3. Cells: Two types of cells are recognized: fixed

cells and wandering cells, the former include the fibroblasts, undifferentiated mesenchyme cells and adipose or fat storage cells (Forrest et al., 1975).

B. Intracellular proteins: Pork muscle cells contain a large variety of proteins, many of which are involved in the glycolytic pathway of muscle metabolism and the contraction relaxation process. These are the so-called intracellular proteins, and they are further classified into two main groups: the sarcoplasmic and the myofibrillar proteins.

1. Sarcoplasmic proteins: Sarcoplasmic proteins are the soluble proteins of the sarcoplasm located within the sarcolemma. These proteins are soluble at ionic strengths of 0.05 or less (Goll et al., 1974). They comprise about 30 to 35% of the total muscle proteins. They include a nuclear fraction, a mitochondrial fraction, a microsomal fraction and a cytoplasmic fraction, based on ultracentrifugation studies (Asghar and Pearson, 1980). As many as 50 to 100 different proteins are known to constitute the sarcoplasm (Goll et al., 1970). Some of these proteins are the nucleoproteins and lipoproteins, the TCA cycle and the electron transport chain enzymes, myoglobin, as well as protein component of the microsomes, sarcoplasmic reticulum, the T-system and the lyzosomes.

2. Myofibrillar proteins are those components of the

unique myofibrillar system within muscle fibers. They are further divided into two subclasses: (1) the myofilamentous proteins, including myosin and actin, and (2) the regulatory proteins, including the tropomyosin-troponin complex, α- and β-actinins, M-protein and C-protein (Maruyama and Ebashi, 1979). According to Asghar and Pearson (1980) all these proteins are involved either in muscle contraction or in its regulation. A detailed discussion on each of the contractile protein has been made by Gergely (1966) and Briskey and Fukazawa (1971).

The Conversion of Pork Muscle to Meat

The conversion of muscle to the component tissue of a cut of meat can be summarized as being the effects of the degradation of ATP in the period from death to postrigor It is true that commercial handling practices after slaughter can influence the subsequent quality of meat, but they can only do this within limits set by the physiological and biochemical characteristics of an animal before and at the time of slaughter (Lister, 1970).

According to Kastenschmidt (1970) the variable rate of postmortem metabolism has important implications in the ultimate usefulness of muscle as food. According to this author "fast glycolyzing" muscle are those having a pH of 5.5 or less at 30 min. postmortem. "Slow glycolyzing" muscle have a pH of 6.0 or higher at 60 min. postmortem. "Stress

resistant" animals are those which can withstand antemortem stress and whose muscles after death are usually slow glycolyzing. Finally, "stress susceptible" animals are those which cannot tolerate antemortem stress. They usually have fast-glycolyzing muscle or expire before they can be exsanguinated.

It is generally accepted that the deficient water-binding capacity of the pork meat is associated with a rapid pH fall after slaughter due to rapid glycolysis. This type of meat has been found less suitable for sausage manufacture and detrimental for the quality of canned hams (Wismer-Pedersen, 1969).

Numerous research efforts have been made to relate live animal parameters to a judgment of the quality of postmortem meat. A color and structure score (Wisconsin system) ranks porcine meat from 1 being pale, soft and exudative (PSE) to 3 being normal to 5 being dark, firm and dry (DFD), (Cassens et al., 1975). It is now known that meat from stress-susceptible animals may be PSE, DFD or even normal in appearance, depending on the handling of the animal before, during and after slaughter. Cooper et al. (1969) made an attempt to explain the cause of PSE condition in porcine muscle. These authors found that stress-susceptible animals present skeletal muscle with a large number of intermediate fibers which are dependent upon aerobic metabolism, but unlike typical red fibers they have especially high ATPase and phosphorylase activity, breaking down ATP and accelerating glycolysis to trigger a rapid glycolytic rate in the entire muscle. Additionally, even the regular white, and to a lesser extent

the regular red fibers have rather intense ATPase and phosphorylase activity and further contribute to the acceleration of these metabolic phenomena in the muscles of stress-susceptible animals. Merkel (1971a) found fewer capillaries per square millimeter in PSE muscle. The fibers of PSE muscle were also significantly larger. He concluded that PSE muscle would be more predisposed to the development of anoxia.

There seems to be little doubt that PSE meat is less desirable for certain processing procedures than is normal meat. PSE hams have been reported to produce gelatinous cookout losses with poor color and texture when compared to normal hams (Cassens et al., 1975; Merkel, 1971b).

Myofibrillar Proteins and Functional Properties of the Meat

The myofibrillar proteins and the connective tissue proteins are fibrous and elongated and form viscous solutions with large shear resistance. These properties together with other lines of indirect evidence (Marsh, 1970; Marsh, 1972), have led to the axiom that variation in meat tenderness is directly and almost entirely the result of variations in the state of myofibrillar and connective tissue protein fractions (Goll et al., 1974).

Although tenderness is an important factor in processed meat production, heat-gelling and emulsification properties are critical characteristics in some types of processed meats such as

comminuted sausage, fine cut sausage and sectioned and formed meat products. Again, myofibrillar proteins, especially myosin, play a fundamental functional role (Briskey and Fukazawa, 1971). According to these authors, myosin appears to have a major influence, whereas actin has little influence on gelation. They also reported that when actin and myosin are combined, however, gel strength is improved and the complex binds more water than myosin alone. According to Hamm and Hofman (1965) the heat coagulation of myofibrillar proteins is attributable to intermolecular associations of side groups (other than sulfhydryl groups) on the molecules. The experiments of Fukazawa et al. (1961a, 1961b, 1961c) show myosin to be a key constituent of the desirable binding quality in experimental sausage.

Trautman (1966) reported that muscle protein characteristics and their food manufacturing properties are decidedly influenced by the rate, temperature and extent of postmortem pH decrease. Decreasing pH reduces salt-soluble protein solubility and heat gelling properties. It also reduces the solubility of water soluble proteins and releases free heme from myoglobin.

The effect of heating on muscle systems, particularly on myofibrillar proteins, has been studied by Hamm (1966). He reported that changes in myofibrillar proteins at 30-50°C include two steps: (1) an unfolding of peptide chain and (2) the formation of relatively unstable cross linkages resulting in a tighter network of protein structure within the

isoelectric range of pH. At 50-55°C a rearrangement of the myofibrillar proteins occurs causing a delay in the changes of water-holding capacity. At these temperatures new cross-linkages begin to form. They are quite stable and cannot be split by addition of weak base or acid. At 55-80°C most of myofibrillar proteins are coagulated. Above 80°C disulfide bonds form by oxidation of the sulfhydryl groups of acto-myosin. Above 90°C H_2S splits off from the sulfhydryl groups of actomyosin.

Some other influences of heating on muscle systems include changes in digestibility, a decrease in vitamins, the development of the flavor and color of cooked meat, and the change in tenderness, resulting from changes in collagen molecules rather than changes in muscle proteins (Hamm, 1966).

Goll et al. (1964) studied solubility of myofibrillar proteins after death. The authors found that significantly greater amounts of protein could be extracted from bovine muscle which had been excised immediately postmortem than from muscles left attached to the skeleton, even after 312 hours postmortem. However, the excised muscles were the least tender, these findings are in contradiction to those of Hegarty et al. (1963), who found a positive relation between myofibrillar protein solubility and tenderness. Sayre and Briskey (1963), studying porcine muscle myofibrillar proteins reported results similar to those by Goll et al. (1964). They demonstrated that myofibrillar protein solubility ranged from no reduction during the first 24 hours after

death when pH remained high at rigor onset to 75% reduction in muscle with low pH and high temperature at the onset of rigor mortis. They also suggested that muscle protein solubility appeared to be one of the major factors affecting the juice-retaining properties of muscle.

The Process of Binding of Meat Pieces

Although an invention related to binding of chunks of meat was patented in the early 1960's (Maas, 1963), little work is found in the literature on the binding of pieces of meat and the mechanism underlining such binding before 1970. At this time, this type of binding became extremely important for the poultry industry, expecially with the advent of new products such as turkey loaves and rolls. In 1970 it was estimated that 25% of all turkey meat was used in the production of these convenience items, (Vadehra and Baker, 1970). These authors found the binding of meat pieces, when appropriately heated, to be complex and involve the following factors: (1) water-holding capacity, (2) cell disrupture and breakage, (3) release of intracellular material, (4) the myofibrillar and connective tissue proteins, and (5) extraneous sources of protein.

Maesso et al. (1970a) reported no difference in binding in turkey and broiler meat pieces (1 inch cubes). However, breast muscle was found to give better binding than leg muscle. The difference in pH in these muscles was reported to have some practical implications.

Acton (1972a) reported a significant decrease in cooking loss along with an increase in binding strength as meat particle size become smaller in poultry loaves. Acton, (1972b) also reported an increase in cooking loss as the internal temperature of poultry loaves increases above 55°C. Acton and McCaskill (1972) found that salt-soluble rather than the water-soluble proteins in poultry meat are responsible for increased meat binding and cooking yield.

Maesso et al. (1970b) reported that mechanical beating of meat releases the intracellular content of broken muscle cells and causes a significant increase in binding. They also reported an increase in binding by NaCl, Kena (Na-tripolyphosphate, tetra-Na-pyrophosphate and Na-acid-pyrophosphate) and hexametaphosphate. When NaCl was combined with Kena they observed a significant additive effect.

MacFarlane et al. (1977) studied the ability of isolated muscle proteins, actomyosin and myosin, to bind pieces of meat together. They found that myosin is able to bind meat pieces not previously subjected to mechanical agitation or having salt added. Actomyosin was found to match myosin in this respect only at high salt concentrations (1.2 and 1.4M).

Schnell et al. (1970) have clearly demonstrated the importance of salt-soluble proteins in binding and reduction of cook loss in chunk-type products. Moreover, these authors concluded that salt-soluble proteins are not the only source of binding materials.

Bard (1965) reported that extraction yields of salt

soluble proteins are influenced by NaCl concentration, extraction time, extraction temperature and the extent of rigor development in the muscle tissue. The author stated that there may be other factors of equal or even greater importance than those reported. Pepper and Schmidt (1975) showed that both salt and phosphates increase the binding strength and cook yield of beef rolls, and that binding strength is higher in the salt-phosphate than in the salt treatments. Similar results were reported by Moore et al. (1976) with beef rolls. Furthermore, these authors reported that the cook yield is closely associated with binding strength.

The effect of phosphates on salt-soluble protein extractability and binding strength of the sausages has been studied by Fukazawa et al. (1961c). They concluded that the ionic strength of the cured meat maintains a condition such that the muscle structural protein is drawn to the outside through the sarcolemma of the muscle cell and that such action may be promoted by the use of phosphates. Furthermore, they stated that the binding quality of sausage has a close relationship to the myosin A (myosin protein) content and to the dissociable components of myosin B (actomyosin complex) with phosphates having the effect of contributing the dissociation of the complex. Fukazawa et al. (1961b) pointed out the importance of suitable amounts of remaining native myosin in fibrils for good binding properties.

The fact that the mechanism of binding between chunks of meat is a heat initiated reaction, as described by Schnell

et al. (1970) and Vedehra and Baker (1970) has led several authors to investigate the gelation properties of myosin. Ishioroshi et al. (1979) reported that the heat-induced gelation of myosin is optimally developed at temperatures between 60 and 70°C and at pH 6.0 in 0.6 M KCl. Yasui et al. (1979) showed similar results to those obtained by Ishioroshi et al. (1979). Furthermore, these authors pointed out that the heat-induced gelation of myosin may be the result of the development of a three-dimensional network structure which holds water in a less mobilized state. Samejima et al. (1969) reported that heavy and light meromyosin fragments have little influence on binding properties. They further concluded that an intact molecule of myosin is required for development of binding properties upon heating.

Schmidt et al. (1981) point out that the properties characteristic of myosin gels suggest that the mechanism behind the gelation of myosin involves the formation of fairly stable bonds by irreversible changes in its quaternary structure that are caused by heating.

Siegel and Schmidt (1979) found that the binding ability of crude myosin preparations are significantly greater than the binding ability of either a muscle homogenate free of fat and sarcoplasmic proteins (a total muscle homogenate) or a non-protein control consisting of salt, phosphate and water. They suggested that ionic interactions are implicated in the binding phenomena.

Turner et al. (1979) reported that crude myosin

extracted from postrigor bovine muscle has a potential use as a meat binding agent, since no myosin was extracted from muscles in either prerigor and postrigor state. They also reported 1 M salt and 0.25% tripolyphosphate in the extracting solution as the best concentrations to obtain maximum yields.

Ford et al. (1978) found significant correlations between overall acceptability of restructured beef steakettes containing added myosin and the flavor, juiciness, tenderness and objective measurements in binding strength. Significant correlations were also found between the objective and subjective assessments of binding strength.

Reynolds et al. (1978) studied the effects of ultrasonic treatment on binding strength in cured ham rolls. They found that ultrasound causes changes in muscle microstructure, increases breaking strength, decreases cooking loss and increases the extractability of salt-soluble protein.

The Technique of Tumbling and Massaging Meat Pieces

The success of meat processing into sectioned and formed meats has been reported by Schmidt (1978). He pointed out that more than 284 million pounds of sectioned and formed hams were produced under federal inspection in 1977. In addition, the same author lists nineteen patents on sectioned and formed meat processes granted since 1963.

Almost all these procedures included tumbling or massaging procedures. Anonymous (1981), reported that according to the U.S. Department of Agriculture, about 2 billion pounds of boneless ham products were manufactured in 1979. About 50% of that tonnage was produced as smoked or cooked boneless or sectioned-and-formed hams (including water/added), and 14% as canned products.

Tumbling, typically used in the domestic cured meat industry, includes both tumbling and massaging action. Tumbling, per se, involves the result of "impact energy" influences on muscle such as would occur in allowing meat to fall from the upper part of a rotating drum or striking it with paddles or baffles. Such action leads to the transfer of kinetic energy to the muscle mass and a resultant temperature rise of the processing material. Massaging is a less physically rigorous process and involves "frictional energy" resulting from the rubbing of one meat surface on another or on a smooth surface of a container (Weiss, 1974).

In both cases brine-injected muscle chunks are placed in massagers or tumblers and subjected to various mechanical treatments. Mechanical work is imparted to the chunks of meat through a process of mixing, churning and pounding in such a manner that the chunks of muscle become soft and pliable and develop a creamy, tacky exudate on their surfaces in the form of a protein coat. The protein coat is then heat coagulated by cooking to form a binding matrix between muscle chunks which allows the product to possess the look

of "intact" muscle foods such as roasts or hams (Theno et al. 1977).

Thus, the binding between meat chunks is concluded to be a heat-mediated phenomenon which causes a structural rearrangement of the solubilized meat proteins, and renders them more susceptible to essential protein binding. The formation of the protein matrix is therefore essential to optimal binding in sectioned and formed products (Theno et al., 1976).

According to Schmidt (1979) the goal of these procedures is the formation of a stable heat set protein gel that will effectively bind legal limits of fat and water in an attractive and palatable meat product packed in such a way to remain wholesome, attractive and palatable for a maximum length of time.

According to Starr (1979), in practice, the purpose of massaging and tumbling meat are to ensure a quality finished product and to obtain the following objectives: (1) maximizing yields, (2) impose color and binding, (3) reduce cooking time, (4) control added substances, (5) reduce inventory and (6) save curing brine. As stated by Woolen (1971) perhaps the most important effect of mechanical working imparted to the meat, other than high yield and homogeneous appearance, is the evening out of the brine distribution and shortening of curing time. This author also suggested that application of tumbling to curing is best achieved by injecting the brine before the first tumble. This process allows the absorption and distribution of the brine. It is followed by a maturing

period, often ending with a second tumble, which is used for the extraction of the salt-soluble proteins to provide for the bonding of meat surfaces when meat is thermally processed. This procedure has led to the development of automated tumblers in which a programmable system allows the meat chunks to be tumbled under vacuum for predetermined intervals and then to equilibrate before tumbled again (Anonymous, 1971).

In some equipment tumbling and massaging are combined. Addis and Schanus (1979) reported on a vacuum massage tumbler designed in Europe. According to these authors, massaging treatment is applied for 10 to 20 hours. Any brine not absorbed by the meat during stitch pumping can be added to the massaging vats and eventually incorporated during massaging.

Weiss (1974) summarized the advantages and disadvantages of tumbling and massaging. He lists the following advantages: (1) improved brine penetration and uniformity of dispersion; (2) uniform color development; (3) improved release of salt-soluble protein enhancing product bind and coherency; (4) development of a more uniform fine texture; (5) improved yield during processing; (6) reduced product weight loss during consumer preparation; (7) production of a finished product with very desirable slicing characteristics. The many disadvantages he lists include: (1) the initial skinning, boning and defatting procedures require expertise and precision; (2) the considerable massaging time required to develop the qualitative aspects associated with the

technique; (3) excessive massaging results in tissue integrity destruction and adverse temperature rise; (4) excessive moisture absorption adversely influencing finished product coherency, bind and appeal; (5) massaging and tumbling equipment primarily European in origin; (6) the technique employs batch production units to produce desirable results; (7) batch production units limited to 1500 pounds or less to facilitate manufacture of finished products with superior quality and consumer appeal.

Research in the United States on the effects of tumbling and massaging started in the 1970's. Siegel et al. (1976 and 1978b) showed that as the massaging time increases so does the level of fat and protein in the exudate of hams, although these increases are more pronounced in the presence of salt and phosphate.

The influence of tumbling and sodium tripolyphosphate (Na-TPP) on salt and nitrite distribution in porcine muscle was investigated by Krause et al. (1978a). The results indicated that both Na-TPP and tumbling significantly increase the migration of salt and nitrite and result in an increase in cure color development. These observations agree with those made by Okerman and Organisciak (1978). The results by Krause et al. (1978a) also indicated that Na-TPP and tumbling increase the level of residual nitrite content, although the tumbled hams have higher levels of cured meat pigments formed.

Krause et al. (1978b) studied the influence of tumbling, tumbling time, trim and Na-TPP on quality and yield of cured hams. They reported that tumbling has a significant influence on external appearance, internal ham color, slicability, taste, yield and aroma. The most dramatic effect, however, is on sliceability and yield. The authors also reported a significant improvement in external color, sliceability, taste and aroma and yield of cured hams independent of the tumbling effect.

Rejt et al. (1978) used massage under vacuum in the elaboration of canned hams. They observed that massaged muscles show a definite change of structure, particularly of surface layers, and an increased water-holding capacity. After heat treatment hams show higher tenderness and lesser cooking loss than the non-massaged meat. Siegel et al. (1978b) reported that the massaging process involves great degrees of tissue destruction at the cellular level which aids in the extraction, solubilization, concentration and distribution of the major myofibrillar proteins on surfaces and interiors of muscle chunks. All these results of massaging are beneficial to the improvement of binding. Theno et al. (1978a, 1979b and 1978c) reported the observation of light and scanning electron microscope microphotographs of tumbled ham material. These authors indentified the presence of fiber fragments in the exudate of hams tumbled for 24 hours regardless of whether salt and phosphate were added to the meat. The treatments with salt and phosphates showed

clouds of solubilized protein. The length of massaging enhanced the effects in all treatments. Further massaging resulted in longitudinal disruption of the fibers shown under the scanning electron microscope. They also reported that at low salt concentrations in the brines, the junctions exhibited poor binding characteristics with high levels of fat and cellular fragments as seen under the light microscope. Junctions from rolls with adequate salt (≥2%) and phosphate (0.5%) exhibited good binding characteristics. Cassidy et al. (1978) made similar observations. In addition, however, they reported that intermittent tumbling resulted in more alterations in cell structure than continuous tumbling.

Ockerman et al. (1978) found increased cohesiveness values in canned hams tumbled for 30 min. when meat was cured with salt and tripolyphosphate. They also stated that tumbling for 30 min. is not sufficiently long to increase yield, texture or sensory characteristics of hams.

Knipe et al. (1981) studied the effect of intermittent tumbling and tumbling temperature on total aerobic plate counts (ATPC) and quality of boneless, cured hams. They showed that a significant rise in internal temperature of the meat can be observed after 3 hours tumbling (10 min. tumbling, every hour, for 18 hours). They also reported that the exudate ATPC is significantly reduced after 18 hours tumbling.

Solomon et al. (1980) studied the effect of vacuum and rigor condition on cure absorption in tumbled porcine

muscles. Their results indicate that vacuum and prerigor state independently increase the absorption of NaCl. They also pointed out that vacuum is implicated in increased binding functionality, since breaking strengths of ham slices were found to be greater when vacuum tumbling was used.

Non-meat Proteins in the Binding of Meat Pieces

Hawley (1977) reported the use of non-meat proteins along with the pumping brine as a technique for augmenting intact muscle protein in hams. They recommended pumping to 145% of green weight in order to obtain finished hams with approximately a 130% yield when cooked (89% smokehouse yield). The procedure also includes massaging or tumbling to assure distribution and equilibration of the brine and vacuum-mixing after tumbling to remove entrapped air from the muscle.

Siegel et al. (1979b) studied the effects of various levels of isolated soy protein (ISP) in combination hams. They reported that massaging and ISP improves both binding and cook yield. Increased levels of injection decrease binding strength and cooking yield. Massaging improves uniformity, textural appeal and overall acceptability, but it decreases tenderness and does not effect juiciness and flavor. In a similar study with ISP Siegel et al. (1979c) reported that ISP occupies primarily perimysial spaces and that

massaging acts to incorporate these proteins into the endomysial spaces and mix them with extracted myofibrillar proteins. According to the authors the ISP appears to enhance myofibrillar protein extraction by binding water, thus increasing the effective concentration of salt and phosphate.

Kardouche et al. (1978) used ISP at different levels up to 3% with pre- and postrigor turkey in the preparation of rolls. They concluded that as the level of ISP increases the flavor, tenderness, texture and acceptability scores increase, and the shear values decrease. They also reported that the level of ISP has greater influence on the shear value than the rigor state of the meat.

Siegel et al. (1979a) ranked the binding abilities of several non-meat proteins in the presence of 8% salt and 2% sodium tripolyphosphate from highest to lowest as wheat gluten, egg white, corn gluten, calcium reduced dried skim milk, bovine blood plasma, ISP and sodium caseinate.

New Trends in the Acceptance by Consumers of Sectioned and Formed Meats

Considerable concern has been expressed over the current dietary intake of fats and additives contained in processed meats.

Kolari (1980) has discussed the salt dietary concern. He concluded that, although current evidence does not provide the basis for drastically reducing salt dietary intake for the general population, moderation needs to be considered

for those at risk of developing essential hypertension.

Marsden (1980) reported that the contribution of the processed meats to the sodium level in the American diet is significant and the meat industry should be aware of its involvement in this controversy. He concluded that sodium-containing additives perform important technological functions in addition to their contribution to flavor. Consequently, if it becomes necessary to reduce the level of sodium in processed meats, the amount of the reduction should not be arbitrarily determined.

Nitrites present in processed meats are thought to pose a health hazard by virtue of their ability to form N-nitrosamines. Many of these compounds are carcinogenic and, in addition, some exhibit mutagenic, embryopathic or teratogenic properties. Although there is no direct evidence the N-nitroso compounds are carcinogenic to man, indirect proof from animal studies on 12 species would suggest this potential danger to man (Gray and Randall, 1979). The argument has been made that discontinuing the use of nitrite as a food additive would greatly reduce or eliminate this risk (Tannenbaum, 1979). However, according to the same author, the risk that might exist from the use of nitrites according to present regulations would be minuscle compared to those resulting from the body's natural processes.

The other point of controversy concerns the fat content in meat and meat products as a major contributor to the development of such chronic diseases as cardiovascular

disease and cancer (Leveille, 1980). This author states that, although there is no scientific evidence to support the recommendation to reduce meat consumption, a challenge should be made to the meat industry to reduce the fat content of both fresh and processed meats.

These points are part of the reasons why today consumers exhibit new preferences related to processed meats. They look for leaner and milder products containing lower levels of fat and additives (salt, sodium, nitrite) than previous products have contained.

The manufacture of sectioned and formed processed meats may prove to be a process in which fat and additives levels can be carefully controlled in order to produce a finished product widely accepted by every segment of the population.

MATERIAL AND METHODS

Description of the Experiment

The study was conducted in two parts in order to rationalize sample collection and duplicate processing yield data. In the first experiment, conducted in the fall of 1980, 60 hams were assigned to fifteen processing treatment groups. Four hams were used per treatment. The experiment was duplicated in the winter of 1981 with 30 hams assigned also to the processing treatment groups. However, only 2 hams (per treatment) were used in this second experiment.

The following sources of variation were considered in the experiments:

A. Tumbling or massaging sequences. Three tumbling sequences were tested.

1. Sixty minutes of mechanical working of the meat was accomplished by keeping the meat for 4 hours inside the tumbler with 15 minutes tumbling and 45 minutes pausing in each hour.
2. One hundred and twenty minutes mechanical working of the meat was accomplished by keeping the meat for 8 hours inside the tumbler with 15 minutes tumbling and 45 minutes pausing in each hour.
3. One hundred and eighty minutes mechanical working of

the meat was accomplished by keeping the meat for 18 hours inside the tumbler with 10 minutes tumbling and 50 minutes pausing in each hour.

B. Tumbling pressure effect: Two pressure conditions during tumbling of the meat were studied.
   1. Vacuum: Meats were tumbled for a period of time given by the tumbling sequence treatment under 25 inches of Hg vacuum.
   2. Non-vacuum: Meats were tumbled as long as required by the respective tumbling sequence at normal atmospheric pressure.

C. Conditions of the meat: Two sources of meat were studied.
   1. Frozen and thawed pork
   2. Fresh pork

D. Level of brine injection: Two levels of brine injection, based on raw meat weight, were studied.
   1. Sixteen percent pumping
   2. Thirty-two percent pumping

Processing treatments identified by code numbers are shown in Table 1.

Statistical Design

The effects of tumbling sequence, tumbling pressure and condition of the meat were analyzed by a 3-way analysis of variance (ANOVA). This part of the design included treatments 1-12, as shown in Table 2a.

Table 1 - Description of processing treatments used in the manufacturing of boneless hams.

Treatment number	Pressure during tumbling of meat		Condition of the meat		Time of mechanical working of the meat			Brine injection level	
	Vacuum	Non-vac.	Fresh	Frozen	60min	120min	180min	16%	32%
1	X			X			X	X	
2	X		X				X	X	
3		X		X			X	X	
4		X	X				X	X	
5	X			X		X		X	
6	X		X			X		X	
7		X		X		X		X	
8		X	X			X		X	
9	X			X	X			X	
10	X		X		X			X	
11		X		X	X			X	
12		X	X		X			X	
13	X		X				X		X
14	X		X			X			X
15	X		X		X				X

Table 2a - Processing treatments as arranged for statistical analysis by 3-way ANOVA.

Tumbling Sequence (min)	Treatment Number			
	Vacuum		Non Vacuum	
	Fresh	Frozen	Fresh	Frozen
60	10	9	12	11
120	6	5	8	7
180	2	1	4	3

The effects of tumbling sequence and level of brine injection were statistically analyzed by a 2-way ANOVA. This part of the design included treatments number 1, 5, 9, 13, 14 and 15, as shown in Table 2b. ANOVA was conducted at the MSU Computer Center using the Statistical Package for the Social Science (SPSS), version 8 (Nie et al., 1975).

Table 2b - Processing treatments as arranged for statistical analysis by 2-way ANOVA.

Tumbling Sequence (min)	Treatment Number	
	16% brine pumping	32% brine pumping
60	10	15
120	6	14
180	2	13

When significant differences were observed between more than two means, the Bonferroni t statistics for

nonorthogonal designed contrasts (Gill, 1978 and Neter and Wasserman, 1974) was performed to determine which means were significantly different. A part of the taste panel results was analyzed by the Chi square method according to Steel and Torrie (1960), and American Society for Testing and Materials (1968).

Source of Meat

Fresh pork was obtained from Peet Packing Co., Chesaning, Mi. Although the requested weight for hams was 16 to 18 lbs. per unit, the hams arriving to our laboratory weighed between 14 and 22 lbs. Fresh hams intended to be used as a fresh meat source were delivered in groups of 4 or 8 units, 1 or 2 days before the date of processing.

Fresh hams intended to be used as a frozen meat source were delivered as a single batch at the beginning of the experiment.

Preconditioning of Fresh Hams

Preconditioning of fresh hams is indicated in Figure 1 as the first stage of the processing flow chart. Fresh hams used as a fresh meat source were vacuum packaged upon delivery into Cryovac (polyvinylidene chloride) bags and kept in a cooler at 2°C until processed. Fresh hams used as a frozen source of meat were individually weighed upon delivery, wrapped in butcher paper and vacuum packaged in Cryovac bags. The packaged meats were then frozen and stored at

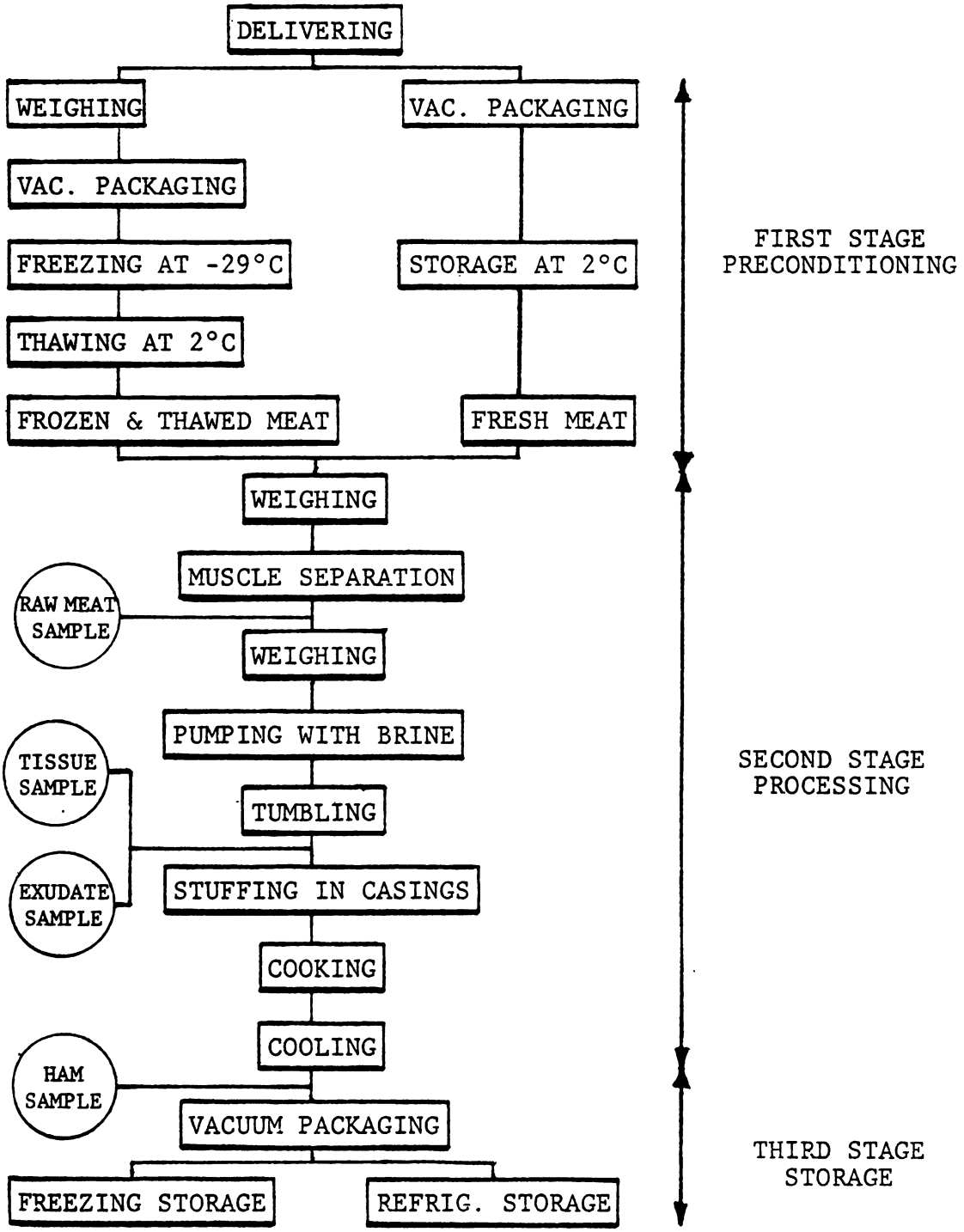


FIGURE 1 - Processing flow chart and sampling points in the manufacturing of boneless hams.

-29°C. The frozen hams were taken out of the freezer as needed and allowed to thaw in the cooler at 2°C for five or six days before processing.

Processing and Sampling Operations

As the flow chart in Figure 1 indicates, the processing of the meat is the second stage in the operation. At this point fresh hams were individually weighed, skinned, boned and separated into muscle groups and the fat was trimmed to less than 1 mm thick. The weight of skin and fat, bones, fines and trimmed muscles were recorded at this stage.

Five different muscle groups were identified and separated from each ham: biceps femoris, semimembranous (with gracilis attached), semitendinous, the quadriceps group (commonly known as the knuckle of the ham) and the gastrocnemius group (commonly known as the mouse of the ham). The trimmed ham muscles were then sampled (labeled as raw meat sample) and analyzed for moisture, fat, protein and lipid oxidation by the TBA method.

The meat was then injected with brine at either 16% or 32% of the raw meat weight by using a stainless steel pickle pump equipped with a spray multiple needle injection system (Hubert Distributing Co., Cincinnati, OH. Catalog numbers SS233EC, 4NH and SNCHA).

All brines contained high grade improved fine flake salt (Diamond Crystal Salt Co., St. Clair, MI.) sugar (Monitor Sugar Company, Bay City, MI.), sodium tripolyphosphate

(FMC Corp., Phosphorous Chemical Div., Newark, CA.), sodium ascorbate (Permacurate Roche, Hoffman La Roche Inc., Nutley, NJ.) and sodium nitrite (analytical reagent, Mallinckrodt Inc., Paris, KY.). Brine compositions are shown in Table 3. The brines were analyzed for salt and nitrite just before the pumping of the meat.

Table 3 - Brine composition as used in the manufacturing of boneless hams.

Ingredient	Concentration in the brine, percent	
	Brine 1 (16% pumping)	Brine 2 (32% pumping)
Salt	13.00	7.03
Sugar	4.87	2.63
Phosphate	1.62	.88
Ascorbate	.36	.19
Nitrite	.10	.05
Water	80.05	89.22

Pumped meat was then placed inside the tumbling machine and tumbled as required by the respective processing treatment in a cooler at 2°C. The tumbler used in this study was a Roschermatic mixing, curing and massaging machine, model MM 80 (Röscherwerke GmbH, Osnabrück, W. Germany), equipped with a mixing arm rotating at 20 r.p.m. The drum was operated at an angle of 40° so that the mixing arm could always grab the meat. Whenever vacuum was required, a Welch Duo-Seal vacuum pump model 1405 (Sargent Welch Scientific Co.,

Skokie, IL.) was used to pull 25 inches of Hg vacuum inside the tumbler.

After mechanical working the meat was taken out of the tumbler, weighed and sampled from the cores of the muscles (labeled as tissue) and from the creamy exudate surrounding the meat pieces (labeled as exudate). Tissue and exudate samples were further analyzed for composition (protein, fat and moisture) by proximate analysis, lipid oxidation, nitrite and salt. Exudate material was also analyzed for soluble phase volume, protein content in the soluble phase and character of the proteins in the soluble phase by sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE).

Tumbled meat was then stuffed into prestuck clear regular fibrous casings, 61 cm long and 14.2 cm diameter (Union Carbide Corp., Chicago, IL.), by using a hand operated jiff net horn (Meat Packers and Butchers Supply Co., catalog number 81135, Los Angeles, CA). Full casings were then tightly sealed using a hand operated stretch clip machine, model J-1 (Global Industrial Machinery Corp. Chicago, IL).

After stuffing, the product was labeled, weighed and secured in tightly stretched stockinette clipped at either end before cooking in a smokehouse.

Cooking of boneless hams was done in an Elek-Trol laboratory smokehouse (Drying Systems Inc., Chicago, IL) according to schedule shown in Table 4. All hams were

cooked to an internal temperature of 68°C.

Table 4 - Smokehouse cooking schedule for boneless hams.

Temperature, °C		Relative	Time in
Dry Bulb	Wet Bulb	Humidity, %	(hours)
60.0	43.9	40	2
71.1	53.3	40	6
80.0	61.1	40	4[1]

[1] This value represents an average time needed to reach 68°C internal temperature in the finished product.

After cooking, the temperature of the hams was brought down overnight in a cooler at 2°C. Then, fully cooked hams were sliced and sampled (labeled as ham). Hams were analyzed for moisture, fat and protein levels, lipid oxidation (TBA), residual nitrite, salt, pigments (cured, total and conversion) and color parameters. Hams were also sampled for texture studies, taste panel and microscopy study on the biceps femoris part of the finished product.

Methods of Analysis

1. Proximate analysis
   a) Protein content was determined by the microKjeldahl method for nitrogen according to AOAC (1965) procedure. Results were expressed as protein percent using 6.25 as a conversion factor for nitrogen values.
   b) Moisture content was determined by the air drying

method of the AOAC (1965) in convection oven at 102°C for 18 hours. Moisture was reported as weight loss percent. Dried samples were saved for fat determination.

c) Fat content was determined by extracting dried samples with anhydrous ether for 5 hours in Goldfisch apparatus, as described in AOAC (1965).

2. Salt analyses were performed according to the official Volhard method by the AOAC (1965).
3. Nitrite determination was made according to methods described on a technical report by the United States Department of Agriculture (USDA, 1979), as modified from the AOAC (1965) method.
4. Lipid oxidation, as a measure of the rancidity of the meat, was determined according to the method by Tarladgis et al. (1960), modified by Zipser and Watts (1962), for cured meats.
5. Cured pigments, total pigments and pigment conversion were determined by the method of Hornsey (1956), as described by Konieco (1979).
6. Color determination was performed by using a Hunter Lab Color/Difference Meter, model D 52-2 (Hunter Associates Laboratory, Inc., Fairfax, VA.). The instrument was standardized against a pink tile with values L = 67.6; a = 21.4 and b = 11.9.
7. Strength of the binding between pieces of meat was assessed in the final product by using a Universal Testing Instrument, model TTC, equipped with a tension

load cell B, which was implemented with the appropriate grip coupling (Instron Corp. Canton, MASS.). Ham pieces approximately 1 cm thick, 2 cm width and 8 cm long and containing a binding zone across the center of the ham piece, were mechanically pulled apart at a constant speed of 2.54 cm/min. The force needed to separate the pieces of meat at the binding line was recorded in a chart running at 2.54 cm/min and calibrated for 2.12 kg force full scale deflection of the pen.

8. Soluble phase volume determination was made by weighing 20 g of exudate and 10 g of 3.9% w/v NaCl solution in a 100 ml homogenizing flask. The mixture was then blended at a low speed in a Virtis "45" homogenizer (Virtis Research Equipment, Gardiner, N.Y.) for 30 seconds. Next, 10 g of the slurry were weighed in duplicate into 15 ml Corex centrifuge tubes and then centrifuged at 2°C for two hours at 40,000 x g in a Sorvall refrigerated centrifuge model RC2-B, equipped with a SS-34 rotor (Ivan Sorvall, Inc., Norwalk, CONN.). After centrifugation 3 layers were clearly visible in the tubes: the upper layer or fat cap, the intermediate layer or soluble phase and the bottom layer composed mostly of connective tissue and muscle tissue fragments. The fat cap was then separated by a small spatula and the soluble phase was allowed to drain into 15 ml graduated conical tubes provided with funnels with two layers of cheesecloth for 15 minutes inside a cooler room at 2°C. The collected

fluid was expressed as soluble phase volume. One ml of soluble phase was next diluted with 1 ml glycerol, stirred in a Vortex tube mixer and stored in a freezer at -20°C for further electrophoretic study.

9. Biuret analysis: Protein content in the soluble phase was made by the microBiuret method described by Goa (1953).

10. Sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) was done by the method of Weber and Osborne (1969), modified by Porzio and Pearson (1977), and adapted for pork muscle proteins as follows:

a) Electrophoresis solutions

(1) Tris-Glycine stock solution (0.5M Tris; 1.5 M Glycine) was prepared in a one-gallon plastic bottle and stored at 2°C.

(2) 25% Acrylamide; 0.25% N,N-Methylenebisacrylamide (BIS) stock solution was prepared and stored at 2°C in plastic bottle. This solution was for 10% gels cross-linked with BIS.

(3) 2.5% sodium dodecyl sulfate (SDS) solution was stored at room temperature.

(4) 1% ammonium persulfate solution was prepared immediately before using.

(5) Chamber buffer solution (0.1% SDS, 0.20 M Tris-Glycine, pH 8.8) was prepared by appropriate dilution of solutions 1 and 3 and adjusted to pH 8.8 with HCl or NaOH solutions.

(6) Tracking dye solution was made of 1.0% SDS, 0.05 M Tris-HCl; 0.5% mercaptoethanol, 20% glycerol and 0.01% Pyronin Y in distilled water. pH was adjusted to 7.2 with 6N HCL and the solution stored in a plastic bottle in freezer at -29°C.

(7) Staining solution was made of 50% methanol, 7% glacial acetic acid and .033% Coomassie brilliant blue in distilled water. This solution was prepared immediately before use.

(8) Destaining solution was made of 7.5% glacial acetic acid and 5% methanol in distilled water.

b) Gel Preparation

(1) 10 ml solution (2), 5 ml solution (1), 1.25 ml glycerol, 1.0 ml solution (3), 0.01 ml of N,N, N',N'-Tetramethylethylenediamine (TEMED), 6.75 ml of water and 1.0 ml solution (4) were combined in a beaker with permanent but soft stirring. The solution was then transferred to running tubes and filled to 8 cm of the tube length. Gels were then overlayed with water and allowed to polymerize for 2 hours.

c) Sample preparation

(1) Soluble phase samples stored in freezer in a 1:1 dilution with glycerol were appropriately diluted with solution (6) to contain 0.4 mg protein/ml. Diluted samples were then heated in a

boiling water bath for 5 min.

(2) A standard purified protein mix containing myosin (MW : 200,000), bovine serum albumin (BSA) (MW : 60,000), ovalbumin (MW : 45,000) and lysozyme (MW : 15,000) was prepared in the same way as the soluble phase proteins. These proteins were mixed in equal parts to make a total protein concentration of 0.4 mg protein/ml.

d) Electrophoresis

(1) The tubes containing the gels were placed in the electrophoresis chamber. Next, the lower and upper buffer chambers were filled with solution (5) and the gels loaded with 50 µl sample. The entry of the sample into the gels was conducted at a current of 0.2 mA per gel. After the dye had completely entered, the current was raised to 0.5 mA per gel and the migration continued until the dye front reached the tube end (10 to 12 hours total run). Electrophoresis was run in a cell Model 150 A connected to a power supply Model 400 and the gels were further destained in a diffusion chamber Model 172 A. All these apparatuses were manufactured by Bio-Rad (Bio-Rad Laboratories, Richmond, CA.).

e) Gel densitometry

(1) Gels were scanned using a Beckman DU Spectrophotometer, Model 2400 (Beckman Instruments,

Inc., Fullerton, CA.) equipped with a gel scanner 2520 and a photometer 252 by Gilford (Gilford Instrument Laboratories, Inc., Oberlin, OH). This system was surfaced to an HP integrator Model 3380 S (Hewlett Packard, Avondale, PA). The gels were scanned at a rate of 1.0 cm/min. and a chart speed of 2.0 cm/min. Start delay and slope sensitivity settings were 0 and 3.0 mV/min., respectively. SDS-PAGE gels were scanned at a wavelength of 550 nm. The relative areas of the individual protein peaks were recorded. The relative mobility of the bands was assessed from the total length of the gel (or tracking dye migration distance) and from the distances migrated by individual proteins.

11. Microscopy study.

a) Sample preparation and fixing: Finished hams were sampled from the biceps femoris muscle by cutting pieces of meat (approximately 20 mm long, 5 mm wide and 2 mm thick) and keeping them in a 10% neutral formalin solution.

b) Dehydrating, clearing and infiltration: This procedure was carried out in an Autotechnicon Model 2 A instrument (the Technicon Company, Chauncey, NY). Fixed tissues first were placed in tissue buttons and then in a basket carrier for the following immersion schedule: 1 hour into each of two 70% ethanol

containers; 1 hour into an 80% ethanol container; 1 hour into each of two 95% ethanol containers; 1 hour into each of two 100% ethanol containers; 1 hour into a 50% ethanol - 50% xylene container; 1 hour into each of two 100% xylene containers; and 2 hours into each of two liquid paraffin containers. Paraffin used was "Paraplast", m.p. 56-57°C (Scientific Products, McGaw Park, IL) at about 60°C.

c) Imbedding: The infiltrated tissue preparations were next imbedded into a plastic disposable boat (approximately 2.5 cubic cm. volume) with melted paraffin and allowed to cool down overnight at room temperature. Then the plastic boats were removed and discarded.

d) Sectioning: Paraffin blocks containing tissue material were mounted in a Minot-Mikrotome, Type 1212 (E. Leitz GMBH Wetzlar, Germany) and cut to a 6 micron thickness. Next, paraffin ribbons containing the sectioned tissue material were floated in a warm water bath containing 2% gelatin and pulled from the ends to remove the wrinkles by stretching the tissue material. The sections were then picked up on glass slides by using a camel hair brush. They were drained approximately 1 minute and finally dried on a light bulb until the paraffin melted down.

e) Staining: Tissue samples were stained with Harris' Hematoxylin and Eosine-Phloxine solutions according

to Luna (1968), with the following schedule of slide immersion: 5 min. into each of two xylene cells; 2 min. into each of two 100% ethanol cells; 2 min. into a 95% ethanol cell; 2 min. into a 80% ethanol cell; 2 min. into a distilled water cell; 10 min. into a hematoxylin cell; 4 dips into a 1% HCl cell; 2 min. into a tap water cell, or until slide was blue; 2 min. into an eosin cell; 2 dips into a 95% ethanol cell; 2 dips into a 100% ethanol cell; 2 min. into a 100% ethanol cell; 2 min. into a 50% ethanol-50% xylene cell; 2 min. into a xylene cell and, finally, 5 min. into a xylene cell.

f) Mounting: Stained preparations were covered with 1 or 2 drops of Pro-Texx mounting medium (Scientific Products, McGraw Park, IL) and topped with a cover-slip glass. These slides were allowed to air dry overnight at room temperature.

g) Microscopic observation: This procedure was done with either a Sterozoom microscope (Bausch and Lomb, Rochester, NY) with 10X and 1X to 7X magnification factors for ocular and objective lenses, respectively, or with a Zeiss photo-microscope III (Carl Zeiss, Oberkochen, West Germany) under 200X magnification factor. Pictures were taken through both microscopes.

12. Taste Panel

a) A semi-trained taste panel was conducted in two sessions with 12 panelists. In the first session

panelists were instructed on the evaluation of slices of hams by visual inspection. Three types of defects were emphasized at this point: color uniformity, surface texture and presence of non-muscle material. The panelists were then asked to evaluate ham slices corresponding to the 15 processing treatments used in this study. The score sheet used in this trial is shown in Appendix A-1. It was then demonstrated to the panelists how to evaluate selected pieces of ham for strength of the binding at the junction line between two chunks of meat.

b) In the second session panelists were asked to evaluate the binding strength by comparing pairs of samples. Four variables were studied in this trial: times of tumbling (short tumbling time versus long tumbling time); use of vacuum during tumbling (vacuum versus non-vacuum); condition of the meat (fresh pork versus frozen and thawed pork); and level of brine pumping (16% pumping versus 32% pumping). Panelists were also asked to evaluate the tenderness or juiciness of the same samples by mouth feeling. The score sheet for this trial is shown in Appendix A-2.

c) Taste panel sample preparation

(1) Samples used in the first session for visual inspection were ham slices (15 cm average diameter and 1.5 cm average thickness). Ham slices

were shown at room temperature.

(2) Samples used in the second session of the taste panel for physical evaluation were cut as 8 cm long, 3 cm width and 0.6 cm thick average ham pieces containing a meat junction or seam line across the length of the meat piece. Samples were offered at room temperature.

(3) Samples used in the second session of the taste panel for mouth feeling or tenderness were cut into 3 cm long by 3 cm width and 0.5 cm thick ham pieces from zones of plain muscle in the finished product. They were offered to the panelists at room temperature.

RESULTS AND DISCUSSION

Chemical Composition of the Raw Meat

Fresh pork and frozen and thawed pork were compared for moisture, protein and fat by proximate analysis and for rancidity by the TBA method. Mean and standard error values for these variables are shown in Table 5. No significant differences ($P \leq 0.01$) between fresh and frozen meat were detected at this point. Protein, fat and moisture content of these meats are quite similar to those reported by Kramlich et al. (1973) for thin separable raw-lean of the pork ham. It is important to note that the low TBA values found in the meats reflect a very sound condition of the raw pork in terms of lipid oxidation.

Table 5 - Proximate composition and TBA values in raw pork meat used in the manufacture of boneless hams.

Condition of the meat	Moisture %	Fat %	Protein %	TBA Nº mg malonaldehyde per 1000g sample
Fresh	71.60±1.31	7.42±1.70	19.94±.62	.135±.050
Frozen	70.02±1.65	8.91±2.07	20.43±.74	.101±.044

[1] N=18

Changes in Chemical Composition Through Processing

Protein content of the meat in the tissue and exudate after tumbling and in the final product is shown in Appendix B-1. A significant increase ($P \leq 0.01$) in protein content with tumbling time was observed in the exudate from fresh meat tumbled with or without vacuum (Figure 2a), but not in the exudate of frozen meat (Figure 2b). Significant interactions between the three factors in study (tumbling time, condition of the meat and pressure during tumbling) are shown in the analysis of the variance (ANOVA) table (Appendix C-1). Figure 3 shows the effect of tumbling time on the protein content in both the exudate and the ham for the meat pumped with brine to 16% and 32%. Protein levels are significantly lower in the exudate from meat injected 32% with brine than those in the exudate from meat injected 16%. This is due to the dilution effect of the higher level of water in the meat system injected 32% with brine. The results also show a significant increase ($P \leq 0.01$) in protein in the exudate with tumbling time (Figure 3a). The significant effects of tumbling time and pumping level on protein in the exudate as well as the absence of interactions between these two factors are shown in the corresponding ANOVA table (Appendix C-2). Protein content in the hams pumped 32% brine were lower than in those pumped 16% (Figure 3b). This was, probably, because the final moisture content in hams pumped 32% was higher than in those pumped 16%.

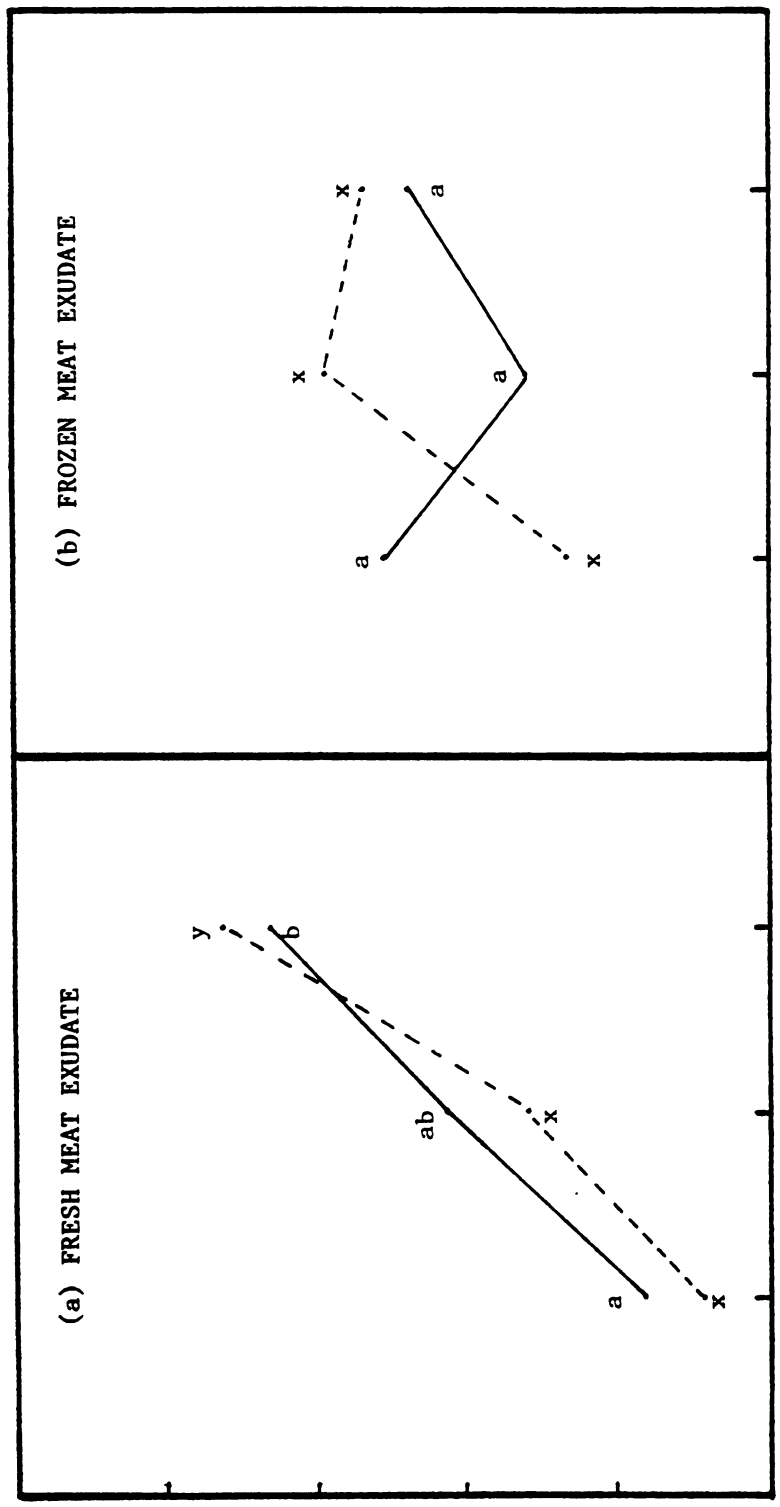


Figure 2 - The effect of tumbling time on the protein content of the exudate and the interactions due to the use of vacuum during tumbling.

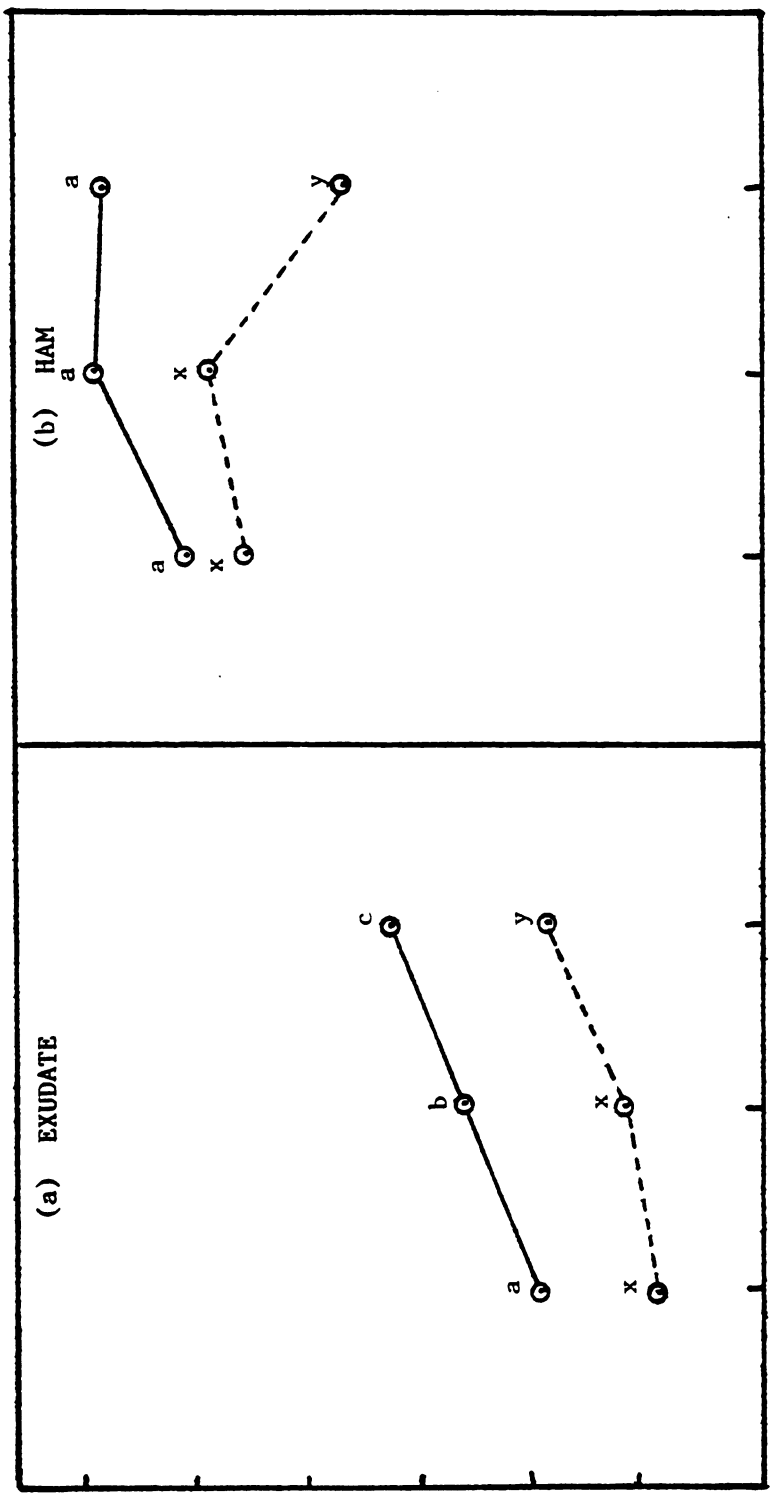


Figure 3 - Protein content (%) in the exudate (a) and in the finished hams (b) as effected by tumbling time and level of pumping.

Fat content in the tissue and exudate after tumbling and in the final product is shown in Appendix B-2. Fat content in the exudate was significantly affected ($P \leq 0.01$) by pressure during tumbling and by tumbling time ($P=0.013$) as shown in ANOVA table in Appendix C-3. The interactions among the three factors are shown in Figure 4. It is important to note that fat level in the exudate increased soon after 60 minutes tumbling without vacuum. There seems to be a rapid release of fat from the muscles to the exudate after a short period of tumbling. This may be due to the fact that most of the fat in the ham muscles is superficial rather than intramuscular fat. Figure 5a shows the effects of tumbling time and pumping level on fat content in the exudate. Although both effects, tumbling time and pumping level, significantly affected fat percent in the exudate (Appendix C-4), the direction of the interactions does not show a trend of variation of fat content in the exudate and in the finished product (Figures 5a and 5b).

Moisture content in tissue and exudate after tumbling and in the final product is shown in Appendix B-3. Moisture content in the exudate was found to be significantly affected by tumbling time and pressure during tumbling ($P \leq 0.01$), as shown in the statistical analysis (Appendix C-5). However, the direction of the interactions (Figures 6a and 6b) indicates no clear effect of tumbling time, pressure during tumbling and condition of the meat on moisture content in the exudate. A decrease in moisture level in the exudate should

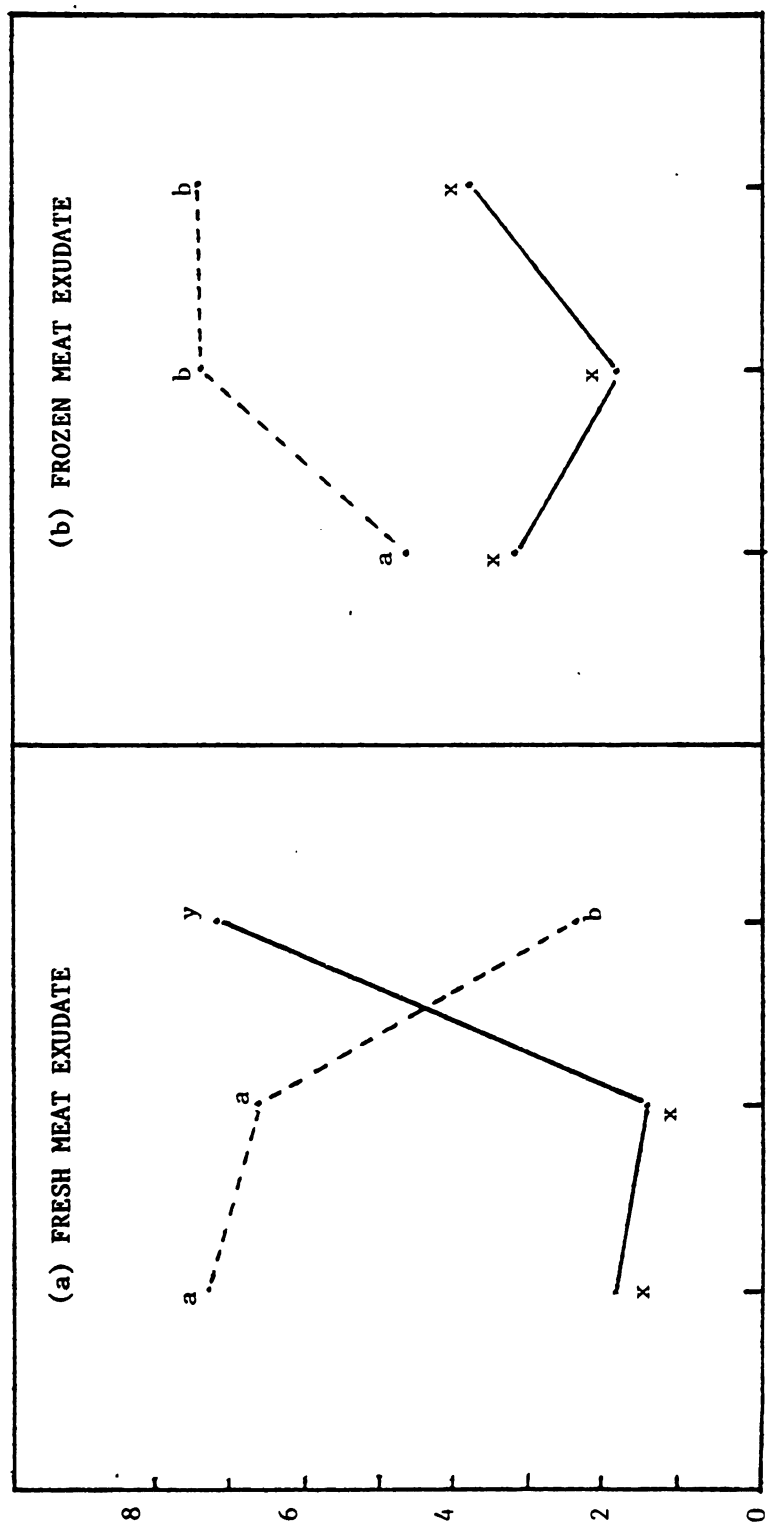
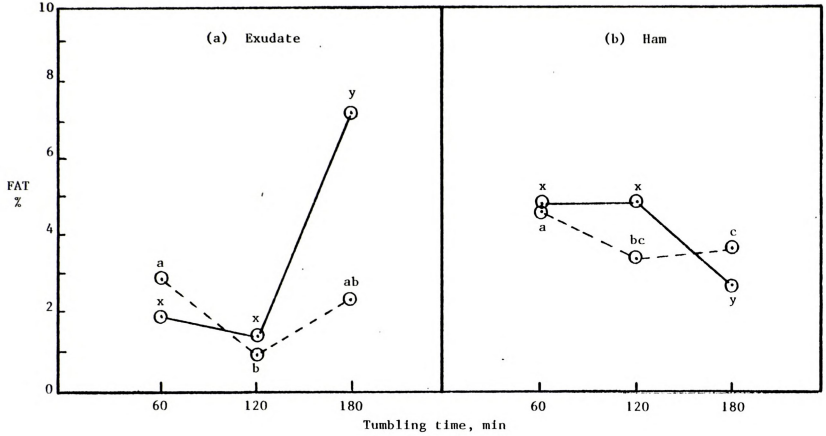


Figure 4 - The effect of tumbling time on fat content in the exudate from fresh meat (a) and frozen meat (b).



Note: Points on the same curve with different superscript letters are significantly different ($P \leq 0.01$)

Figure 5 - Fat content in the exudate (a) and finished hams (b) as effected by tumbling time and brine pumping level.

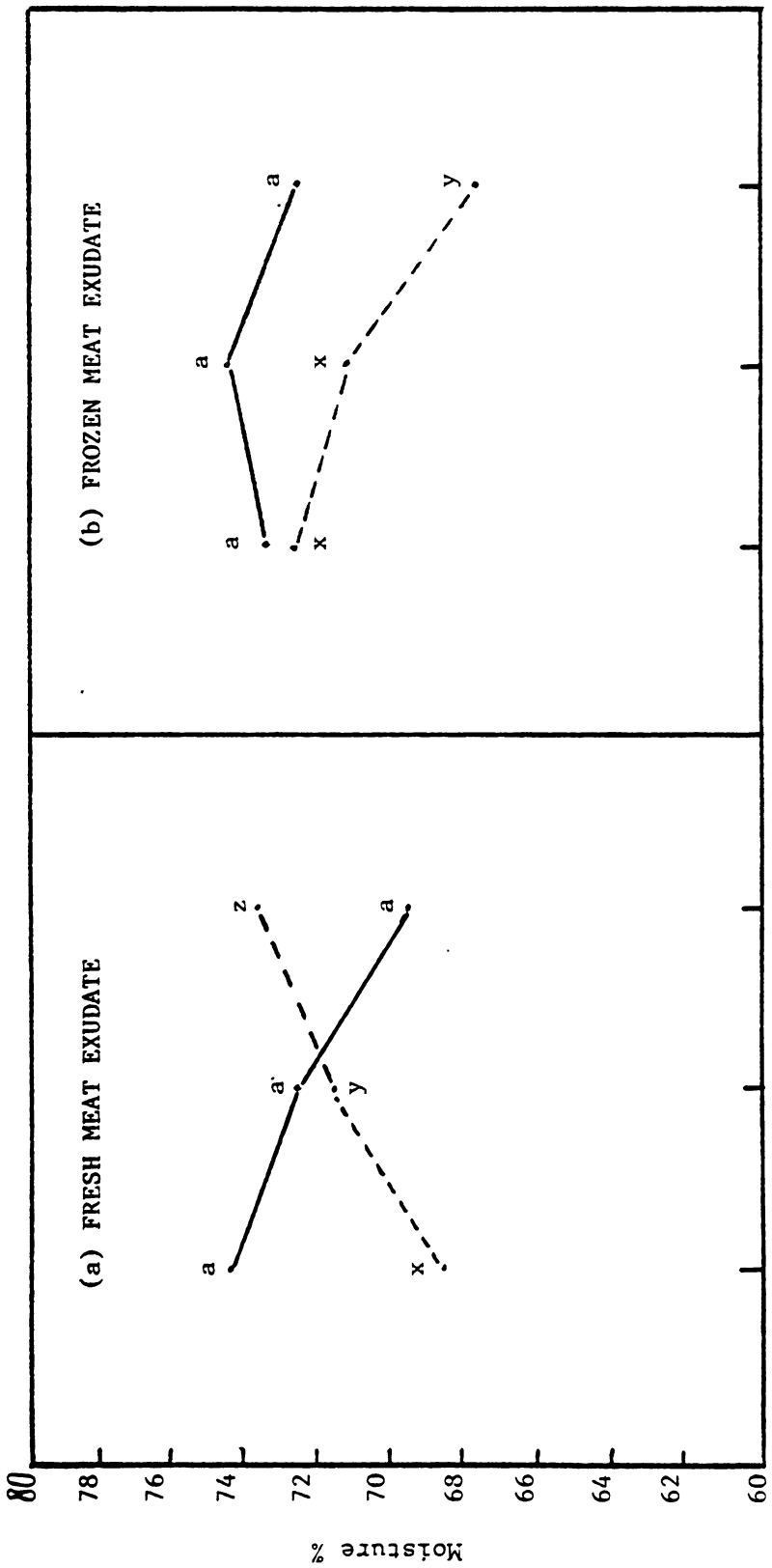
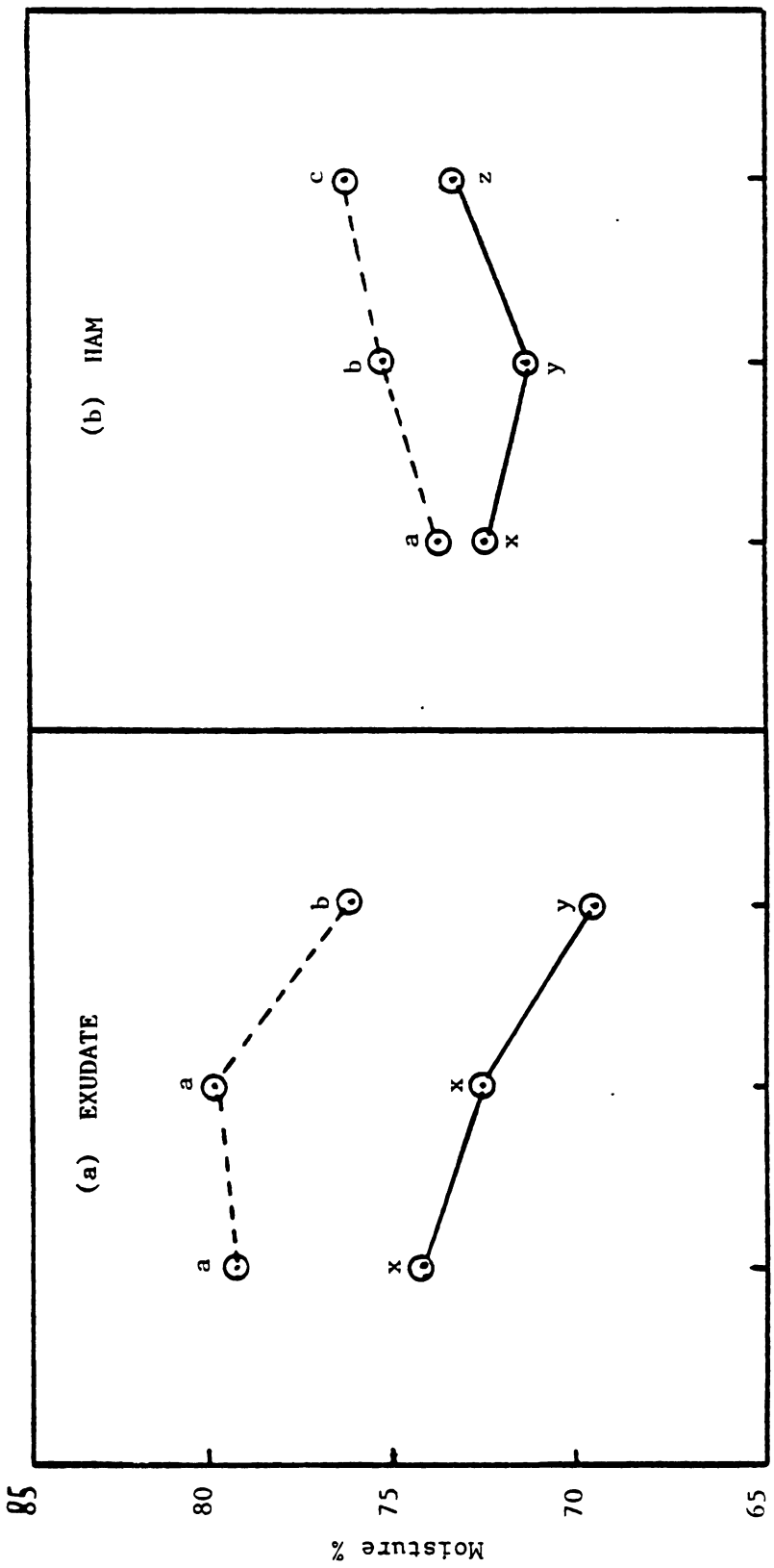


Figure 6 - Moisture content in the exudate of fresh (a) and frozen (b) meat as effected by condition of the meat, tumbling time and pressure during tumbling interactions.

be expected as a consequence of the increase in protein and fat together. Yet frozen meat rather than fresh meat was found with this type of behavior as shown in Figure 6b. The significant decrease in moisture in the exudate of frozen meat tumbled without vacuum could be associated with an increased water-holding capacity by the frozen meat with tumbling time. This observation tends to agree with those reported by Rejt et al. (1978). These authors suggested that loosening of the muscle structure, as a result of massage or tumbling facilitated penetration of curing salt deep into the muscle. This phenomenon may influence the water-holding capacity of the meat, both with respect to water bound by hydration centers and the so-called "capillary water". Frozen meat seems to be more susceptible to tissue damage during tumbling than fresh meat because of the physical stress of freezing and thawing on the fibers. Therefore, water and cure ingredients will penetrate frozen meat better than fresh meat during tumbling.

The effect of pumping level on moisture content on the exudate and the finished product is shown in Figures 7a and 7b. As expected, moisture content was lower in the meat pumped 16% than in the meat pumped 32% in both the exudate and ham. There is a clear tendency for the moisture to decrease in the exudate and to increase in the finished product with tumbling time. In the finished product the hams apparently retained more water as tumbling time increased and more protein was extracted. Again, an increase in



16% pumping, fresh meat, vacuum
32% pumping, fresh meat, vacuum

Note: Points on the same curve with different superscript letters are significantly different ($P \leq 0.01$)

Figure 7 - Moisture content in the exudate (a) and finished hams (b) as effected by tumbling time and brine pumping level.

water-holding capacity was apparent in the meat as tumbling time increased.

TBA numbers for the meat system through the process are shown in Appendix B-4. A significant effect ($P \leq 0.01$) of pressure during tumbling and tumbling time on exudate TBA values was observed (Appendix C-6). The effect of vacuum was evident with frozen meat but not with fresh meat as shown in Figure 8a. The TBA values of frozen meat tumbled without vacuum were significantly higher ($P \leq 0.01$) than those for frozen meat tumbled under vacuum. This is most likely a result of the presence of oxygen in the system without vacuum which tends to accelerate lipid oxidation and thereby increase TBA values. The effect of tumbling time is shown in Figure 8b. Again the frozen meat showed TBA values which was significantly higher ($P \leq 0.01$) at 180 min tumbling than at either 60 or 120 min. tumbling. The effect of pumping level on TBA number in the exudate and the finished hams is shown in Figures 9a and 9b, respectively. Percent pumping caused no significant differences in TBA number of the exudate (Figure 9a and 9b). It is important to note that overall TBA values in the meat system were quite low (less than 0.30) throughout the process of manufacture of boneless hams. The presence of nitrite in the cure seemed to protect the meat against lipid oxidation quite efficiently through the process. According to Kramlich et al. (1973), nitrite retards development of rancidity in cured meats. Furthermore, Fooladi et al. (1979) have reported that nitrite protects raw meats

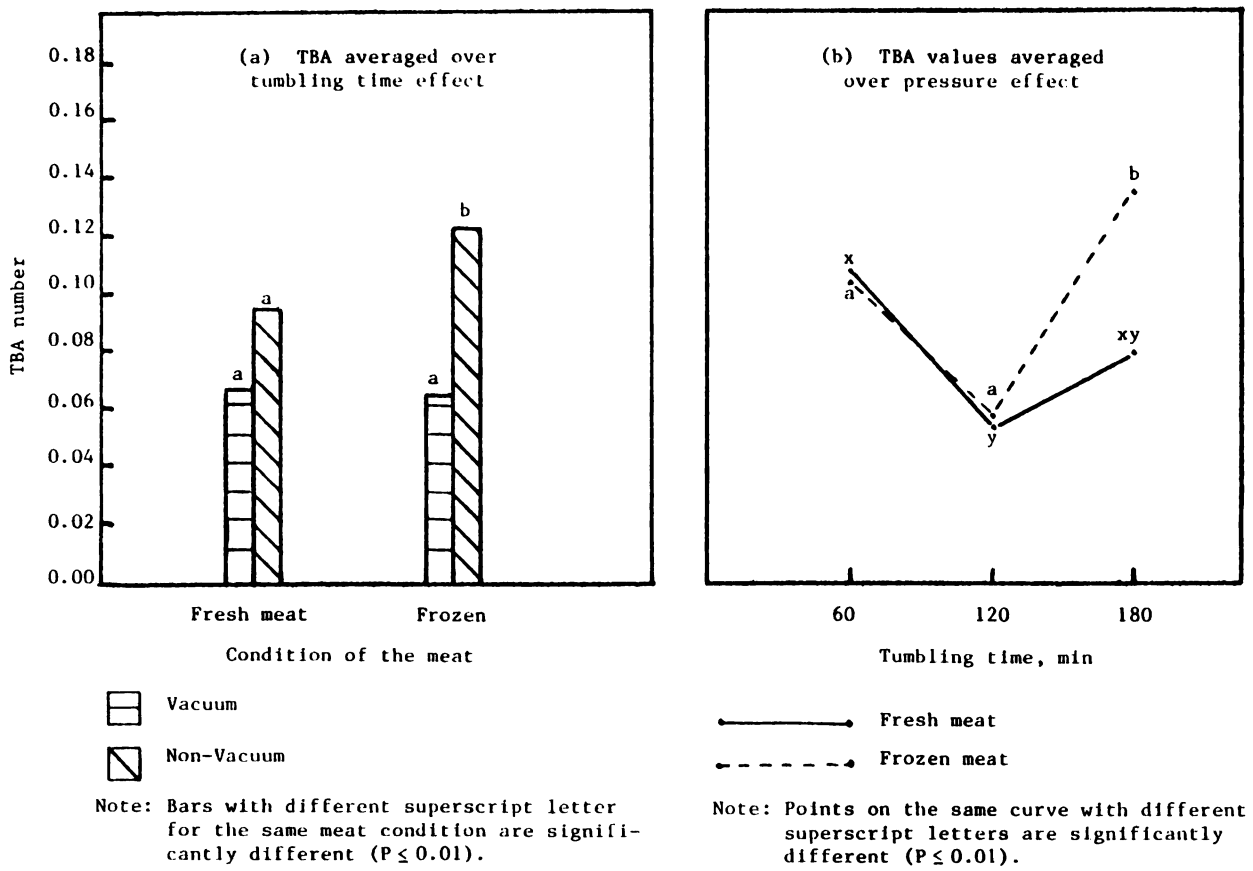


Figure 8 - TBA number (mg malonaldehyde/1000 g sample) in the exudate of pork muscle as effected by condition of the meat and tumbling time.

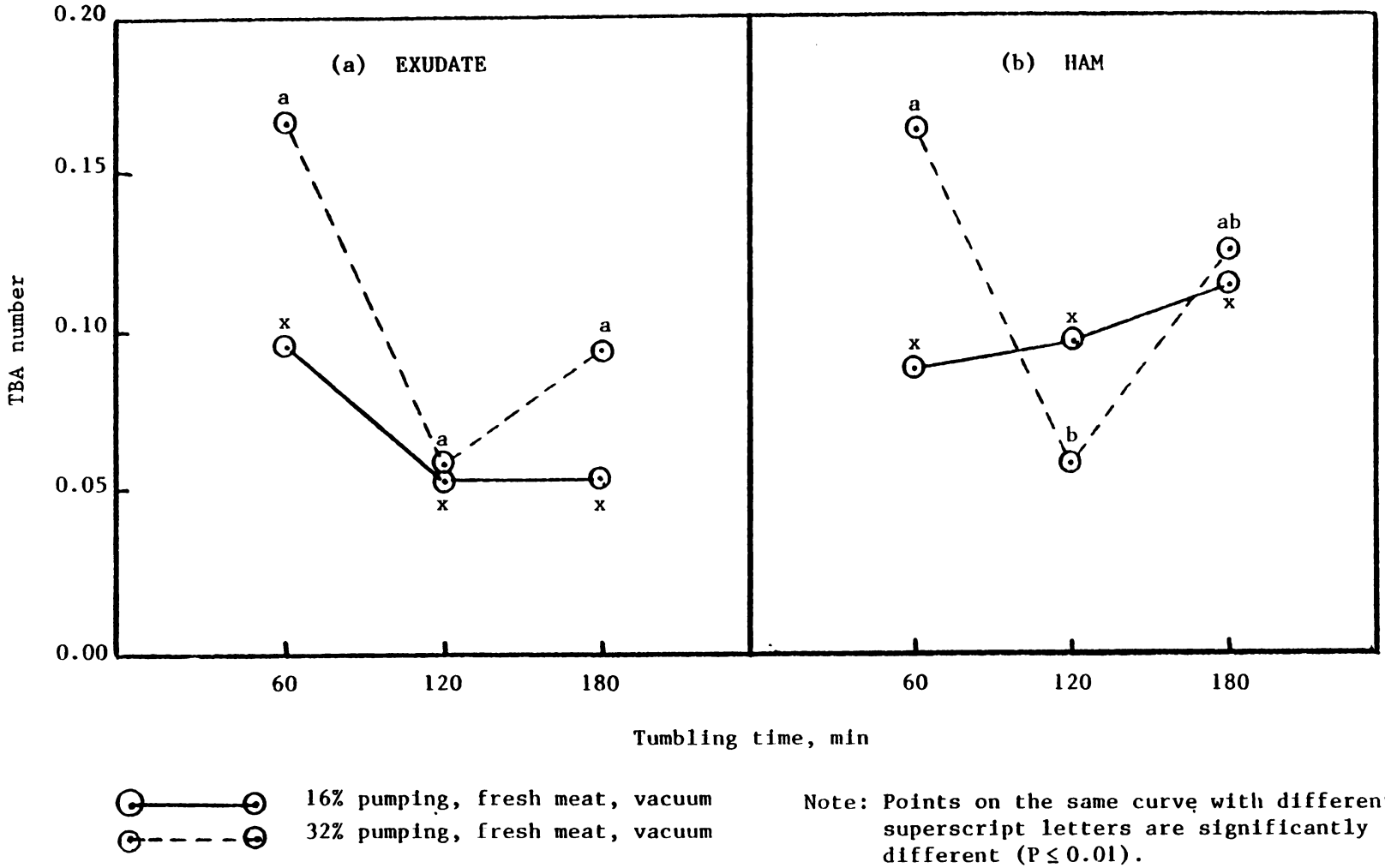


Figure 9 - TBA number (any malonaldehyde/1000 g sample) for exudate (a) and finished hams (b) as effected by tumbling time and pumping levels.

against autoxidation, it also protects against oxidative changes during cooking and against the rapid oxidation that occurs during development of warmed-over flavor in cooked meats. The results in this study also agree with observations made by Zipser et al. (1964). They reported that nitrite inhibits lipid oxidation in cured meats by converting the meat pigments to the catalytically inactive ferrous nitric oxide hemochromogen. The tumbling conditions used in this experiment seemed to favor the protection of the meat against lipid oxidation by nitrite since mechanical agitation provided greater chance for nitrite to react with the pigments during tumbling.

Salt content in the meat system is presented in Appendix B-5. The small variation of salt concentration in the tissue and exudate after tumbling that was observed, indicates that this cure component diffuses quite well through the muscle tissue after a short period of tumbling. A significant effect of tumbling time was observed in the statistical analysis (Appendix C-7). The condition of the meat, tumbling time and pressure during tumbling interactions are shown in Figure 10. Salt concentration tended to decrease in the exudate from frozen meat with tumbling time (Figure 10b). Salt in the frozen meat exudate after 180 min. was significantly lower than that after 60 min. tumbling. The tendency of salt to diffuse more easily in muscle subjected to freezer storage may be due to the effect of cell disrupture by ice crystal formation and/or growth during freezing. This

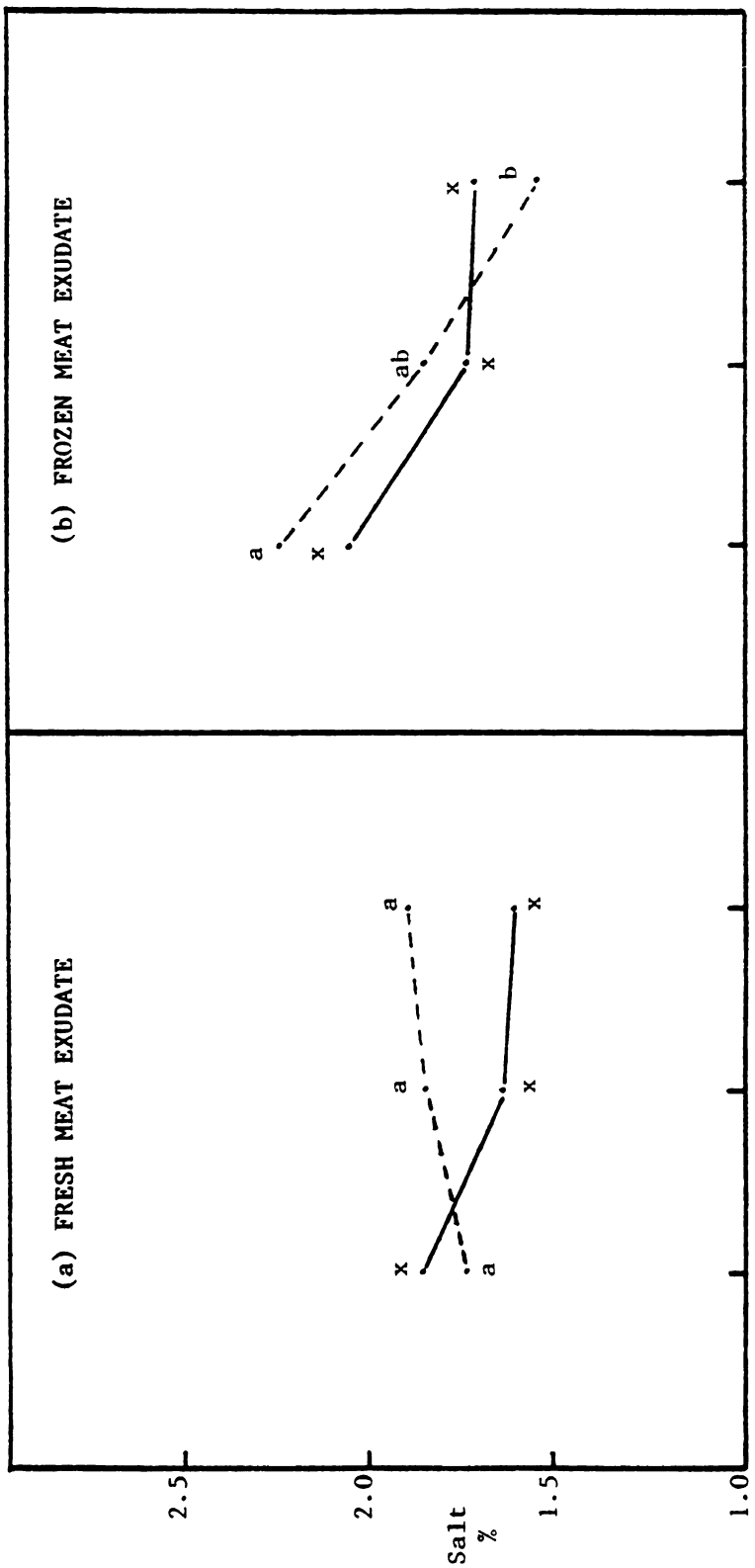
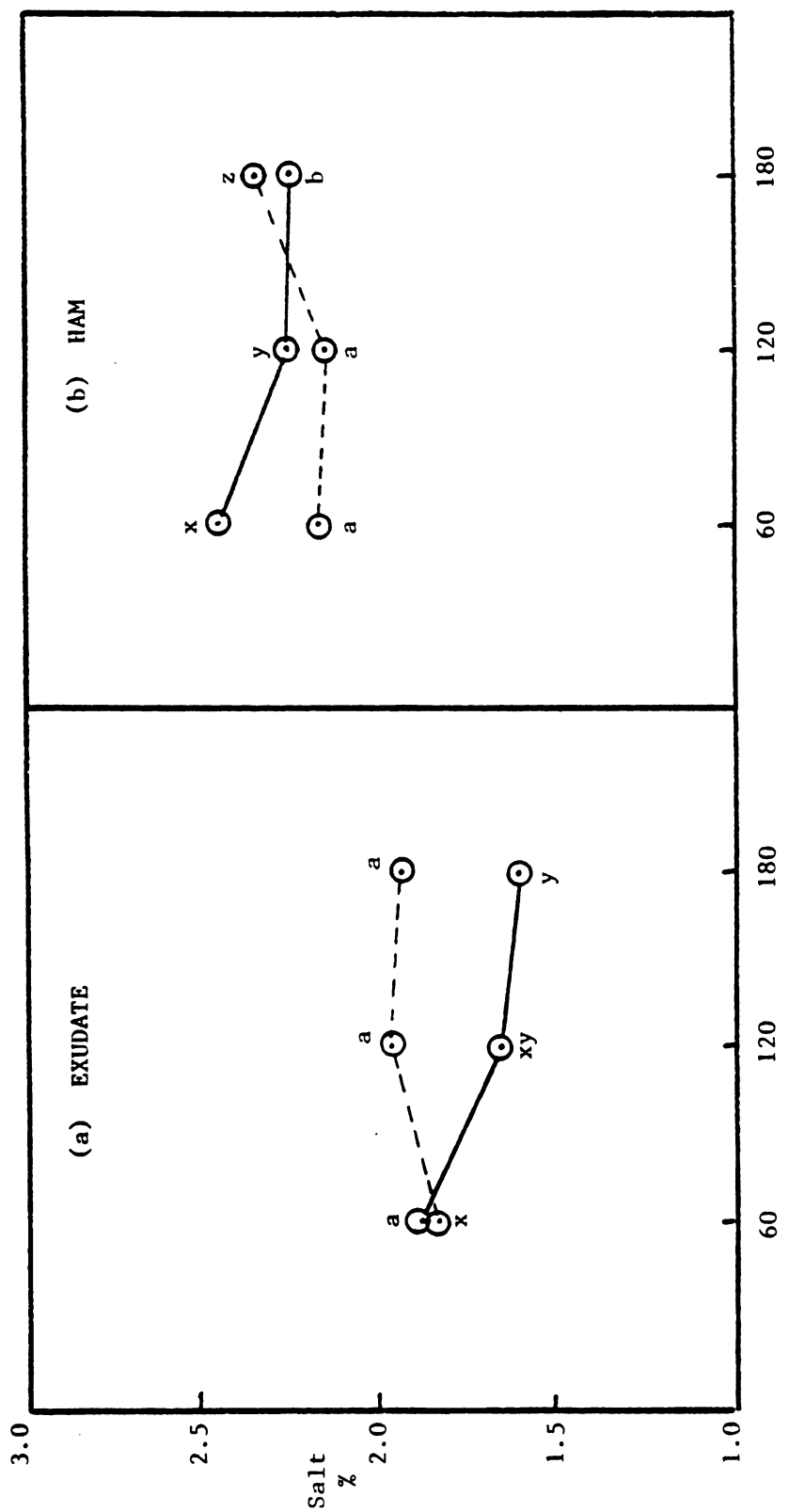


Figure 10 - Salt content in the exudate of fresh (a) and frozen (b) meat as effected by tumbling time and pressure during tumbling.

alteration in the fibers may facilitate diffusion of small ions like sodium and chloride into the muscle fibers. Solomon et al. (1980) reported that vacuum during tumbling significantly increased ($P \leq 0.01$) the absorption of NaCl. On the other hand, Ockerman and Organisciak, (1978) reported that tumbling improves cure diffusion. The results with frozen meat in this study (Figure 10b) show that condition of the meat rather than the use of vacuum during tumbling more drastically affects the absorption of salt from the exudate by the meat tissue. No significant effect of tumbling time on salt in the exudate of the meat pumped 32% was observed (Figure 11a). Salt content in the finished hams was very similar for the meat pumped either 16% or 32% with brine (Figure 11b). These results show that salt concentration in the 32% pumping brine was quite appropriate to obtain hams with final salt concentration equivalent to those injected 16% with the high salt brine (Table 2 in Material and Methods section).

Nitrite levels in the meat system are shown in Appendix B-6. Residual nitrite level in hams was considerable lower than those in the tissue and exudate after tumbling. This effect is probably a result of the considerable amount of nitrite reacting with ascorbate, myoglobin and other meat components before and during cooking. According to Cassens et al. (1979) nitrite reacts with myoglobin first to form metmyoglobin, a brown pigment. However, under reducing conditions, like the ones used in this study because of the



Note: Points on the same curve with different superscript letters are significantly different ($P \leq 0.01$).

Figure 11 - Salt content, percent, for exudate (a) and finished hams (b) as effected by tumbling time and pumping levels.

presence of ascorbate in the brines, the color is converted to the rather dark red of nitrosylmyoglobin. During cooking, this pigment is converted into the stable nitrosylhemochrome, which is pink. Nitrite can also react with non-heme protein (Kubberød et al., 1974) binding to the sulfhydryl groups. According to Goutefongea et al (1977) nitrite reacts with adipose tissue when conditions are similar to those for meat curing. Nitrite can also be converted into nitrate (Lee et al., 1978), especially in the presence of the reductant sodium ascorbate, as is the case in this study (Newmark et al. 1974). Finally, nitrite can be converted into NO and N_2 gases during the mixing stage of cured meat manufacture (Sebranek et al. 1973). It was observed in this study that during tumbling of the meat, nitrite finds great chances of reaction inside the tumbler, not only with the meat components discussed above but with ascorbate present in the cure brine. It is important to note that during tumbling nitrite can also interact with some components of the connective tissue fraction of the meat, such as proline, which may lead to the formation of nitrosamines in the final product (Gray and Dugan, 1975). However, there are some factors during the processing steps followed in this study which tend to decrease the possibility of nitrosamine formation: (1) The source of meat used in this experiment was quite low in both fat and connective tissue (muscles were trimmed to less than 1 millimeter fat thickness) which decreases the proline content in the meat. (2) The formation of various N-nitroso compounds

can be blocked by the presence of ascorbate in the system. According to Mirvish et al. (1972) the inhibitory effect of ascorbate on formation of nitrosamines is that nitrite is "used" so that it is unavailable for N-nitrosation because the rate of reaction of nitrite with the reductant is greater than it is with given amines in the system. (3) During cooking of the meat internal temperature was raised to 68°C which is below the critical temperature (80-100°C) at which N-nitrosamine formation is accelerated (Gray and Dugan, 1975).

Tumbling time and pressure during tumbling significantly affected ($P<0.01$) the content of nitrite in the exudate (Appendix C-8). The significance of the interactions is shown in Figure 12. Tumbling fresh meat under vacuum or without vacuum resulted in significantly higher ($P<0.01$) nitrite levels in the exudate after 180 min. tumbling. The opposite pattern was observed for frozen meat (Figures 12a and 12b). Assuming that the initial concentration of nitrite in the exudate is higher than in the tissue (some injected brine comes out of the tissue right after stitch pumping), then the recapture of nitrite by frozen meat seemed to be more efficient than that by the fresh meat. Fresh meat probably retains the injected brine better than frozen meat in that during extensive tumbling, the nitrite tends to leave the tissue rather than to diffuse into it. The similarity of the pattern of nitrite and salt diffusion from the exudate to the tissue (Figures 10b and 12b) indicates that the frozen meat tended to absorb much of the curing salts during tumbling.

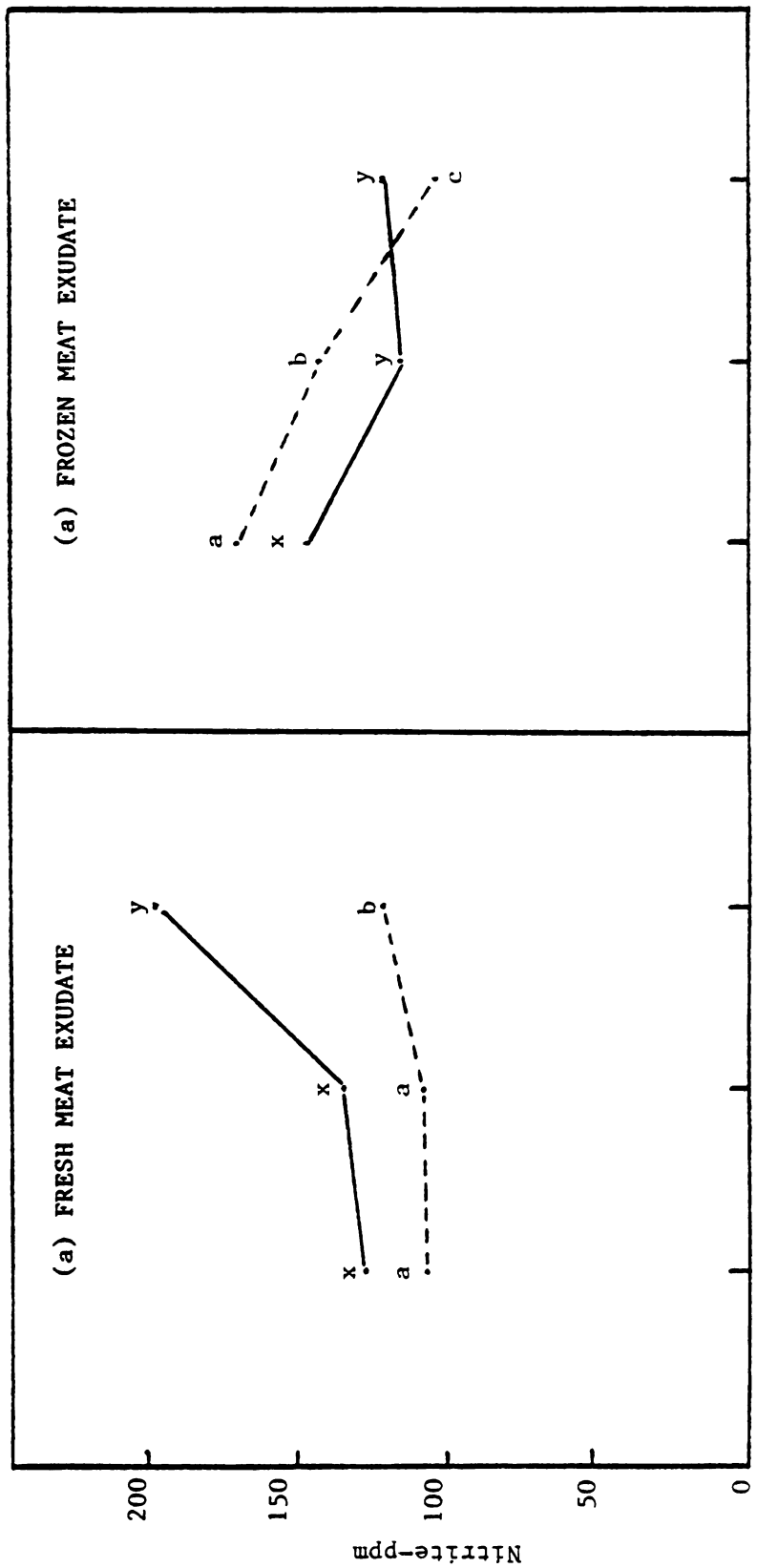


Figure 12 - Nitrite content in the exudate from fresh meat (a) and frozen meat (b) as a function of tumbling time.

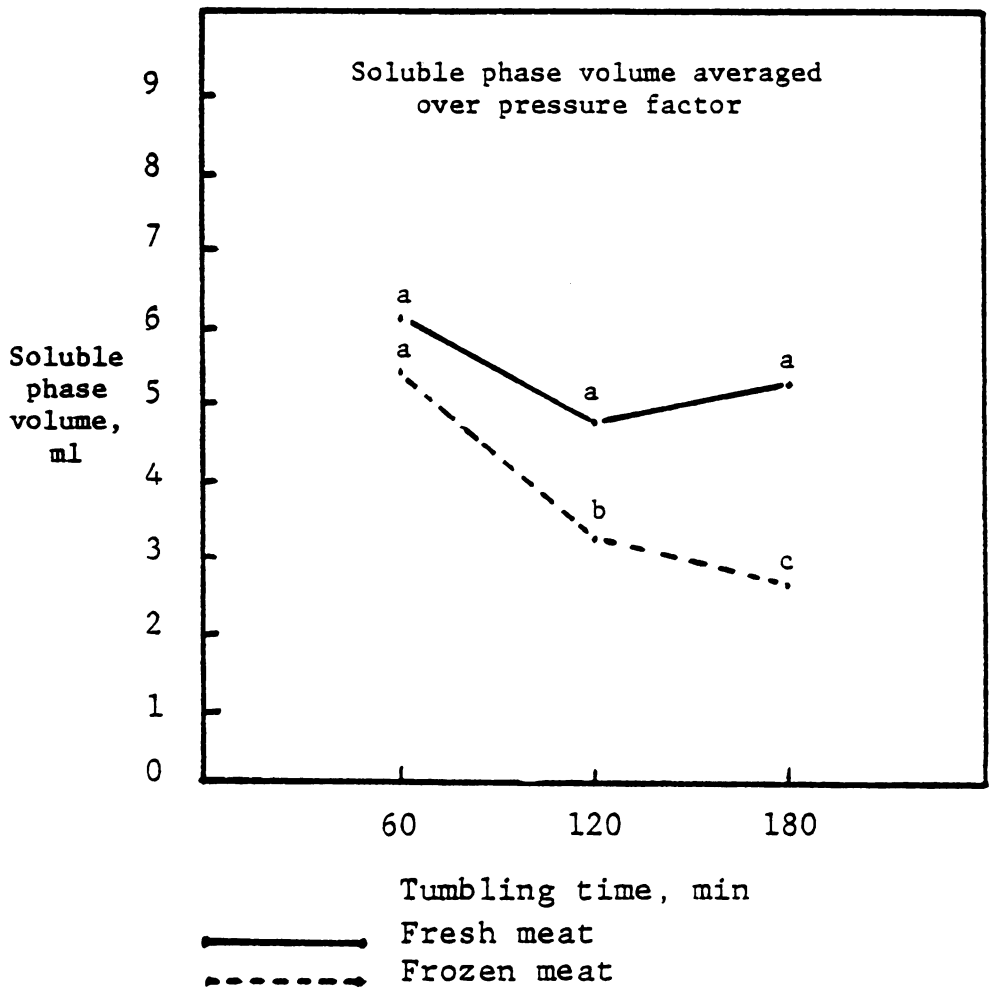
The Parameters of the Exudate

Table 6 shows average values for soluble phase volume. A significant effect of tumbling time and condition of the meat ($P \leq 0.01$) on soluble phase volume was detected (Appendix C-9). A significant interaction between these two effects is shown in Figure 13. A decrease in the volume of soluble phase was observed with tumbling time. This occurrence was more readily noticed in the system with frozen meat. It appears that one of the reasons for the decrease in soluble phase volume was the increase in relative viscosity of the phase as both tumbling time and protein concentration increased. Collection of soluble phase volumes from viscous solutions was much more difficult because of the slow flow of the material. As expected soluble phase volume for meat 32% pumped was slightly higher than that of from meat 16% pumped (Figure 14). This is probably because 32% pumped meat showed a more fluid exudate with lower relative protein and fat concentrations.

Table 6 - Means[1] of soluble phase volume of the exudate formed during tumbling of hams.

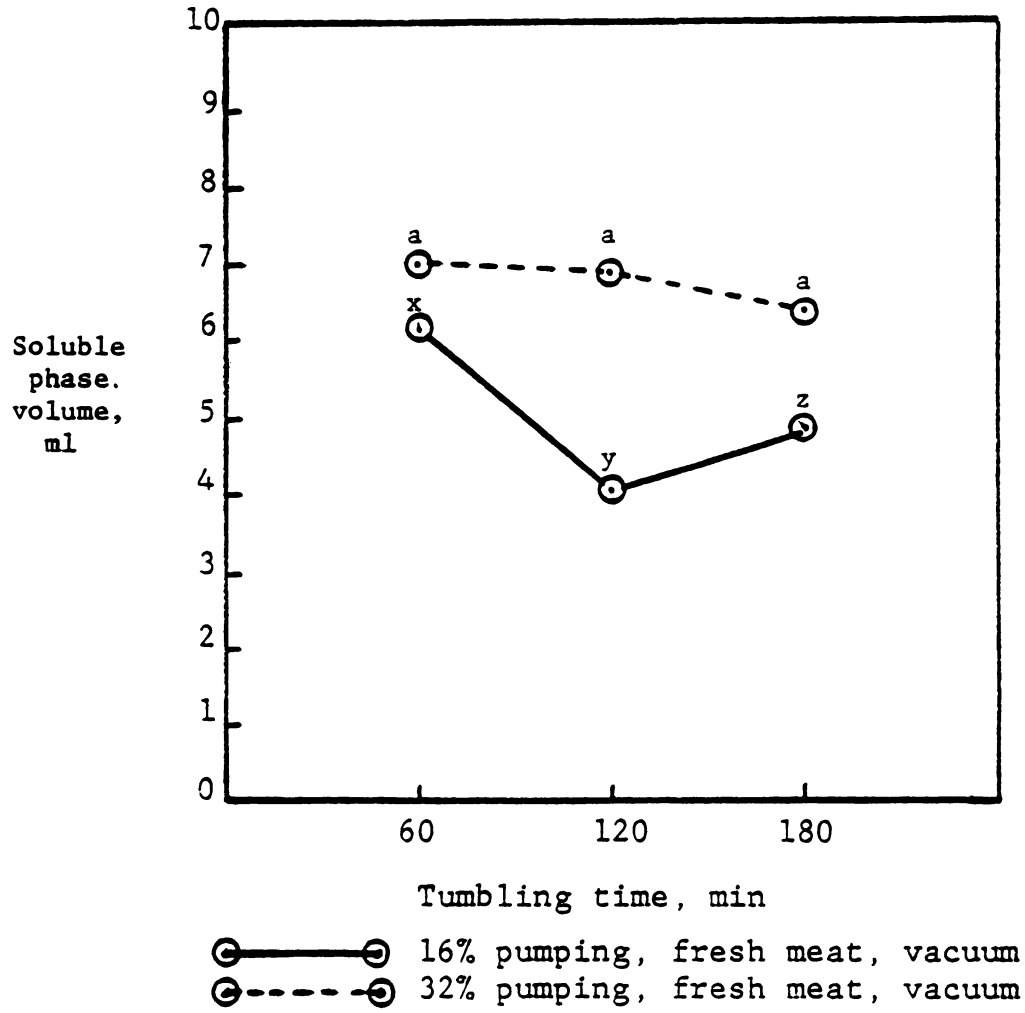
Tumbling time (min)	Vacuum		Non Vacuum	
	Fresh (ml)	Frozen (ml)	Fresh (ml)	Frozen (ml)
60	6.15	5.10	6.00	5.70
120	4.05	3.65	5.45	2.90
180	4.85	-	5.65	2.65

[1] N = 2
Stat error = ±0.32



Note: Mean points with different superscript along the same curve are significantly different ($P \leq 0.01$).

Figure 13 - Soluble phase volume (ml), averaged over the pressure factor, as a function of tumbling time.



Note: Points on the same curve with different superscript letters are significantly different ($P \leq 0.01$)

Figure 14 - Soluble phase volume (ml) in the exudate as a function of tumbling time and pumping level.

The protein content of the soluble phase as determined by Biuret method is shown in Table 7. Statistical analysis for this variable showed significance ($P \leq 0.01$) in all the main effects and interactions (Appendix C-10). Although tumbling time did not affect the amount of protein in the exudate soluble phase of fresh meat (Figure 15a), exudate soluble phase from frozen meat showed protein levels, after 180 min. tumbling significantly higher ($P < 0.01$) than those after 60 minutes tumbling (Figure 15b). This effect may be due, in part, to the relatively high fragility in the muscle tissue of frozen and thawed meat which may facilitate brine entry to the tissue and protein release from the tissue to the exudate. An estimation of the total amount of salt-soluble protein in the soluble phase could be done by multiplying soluble phase volume values (Table 6), by those of protein in the soluble phase (Table 7). However these results tended to show no substantial variation in the total amount of salt-soluble protein extracted. As expected, the protein content in the soluble phase of the meat injected 16% was significantly higher ($P \leq 0.01$) than that of the meat injected 32%, with no significant effect of tumbling time (Figure 16). Salt-soluble protein was, probably, more diluted in the exudate of the 32% pumped meat than in that of the 16% pumped meat.

Table 7 - Mean[1] of protein content (mg/ml) in the soluble phase as determined by the Biuret method.

Tumbling time (min.)	Vacuum		Non Vacuum	
	Fresh (mg/ml)	Frozen (mg/ml)	Fresh (mg/ml)	Frozen (mg/ml)
60	55.45	53.85	58.05	46.70
120	58.75	54.90	54.75	58.00
180	58.80	97.40	52.90	69.40

[1]N = 2

Std. error: ±2.65

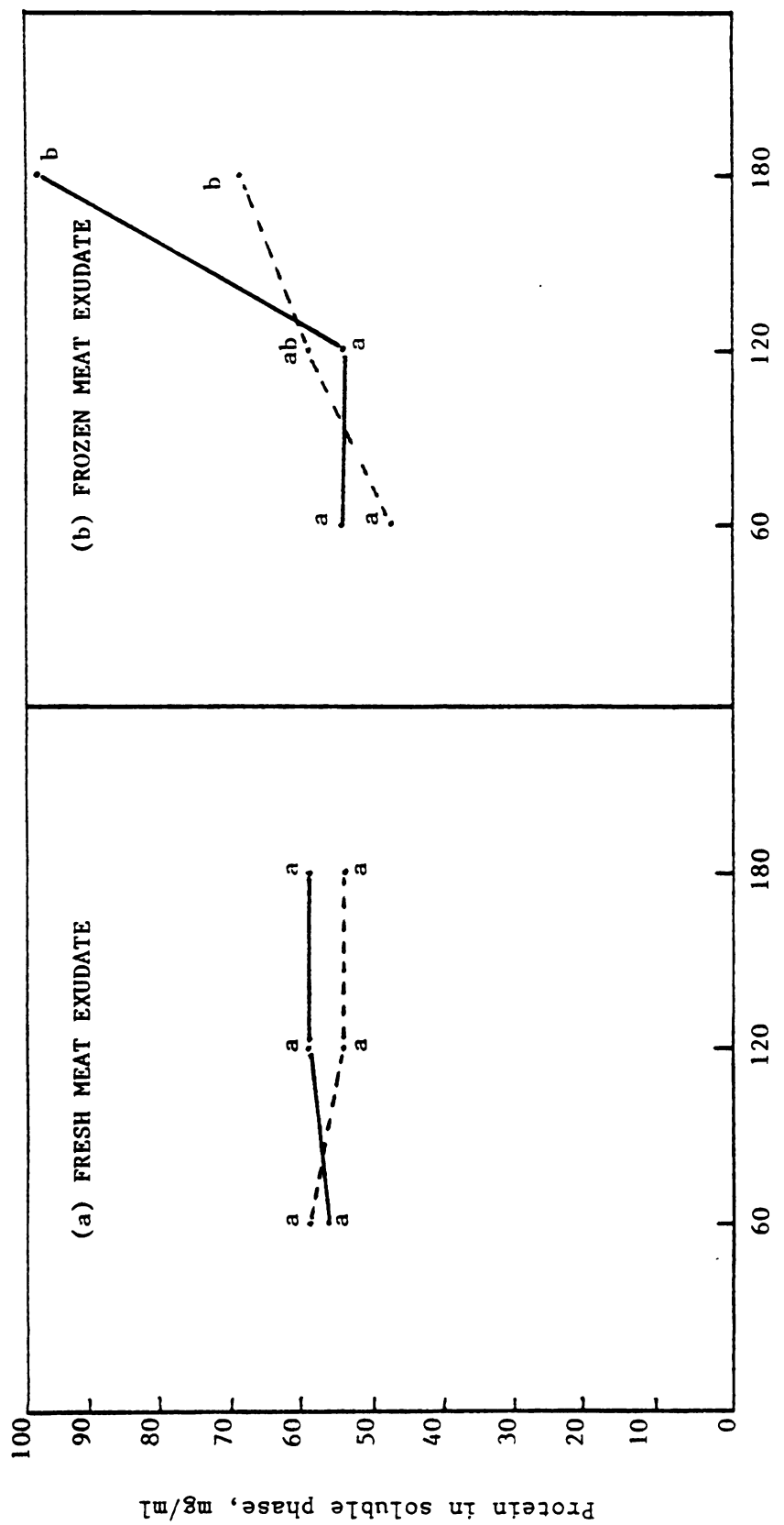
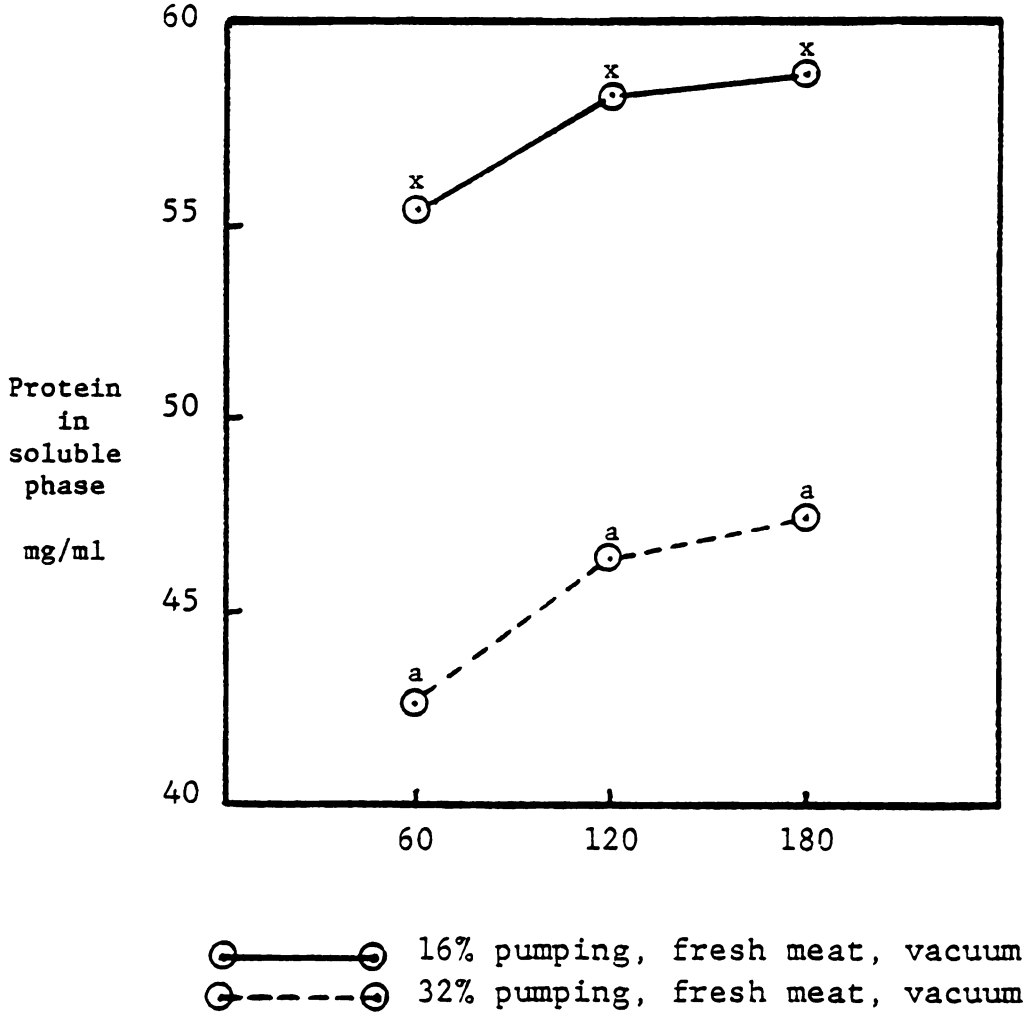


Figure 15 - Protein content in the soluble phase from fresh (a) and frozen (b) meat as effected by 3-way interactions of the major effects.



Note: Points on the same curve with different superscript letters are significantly different ($P \leq 0.01$)

Figure 16 - Protein content (mg/ml) in the exudate soluble phase as effected by tumbling time and pumping level.

Composition of the Soluble Phase

Figure 17 shows the relative mobility of several proteins as obtained in sodium dodecyl sulfate-polyacrylamide gel electrophoresis (SDS-PAGE) as a function of molecular weight. The regression line shown in this figure was calculated and built on the basis of four standard proteins: myosin heavy chain, MHC (Approximate MW = 200,000); bovine serum albumin, BSA (Approximate MW = 60,000); ovalbumin (Approximate MW = 45,000) and lysozyme (Approximate MW = 14,000). Next, the most common myofibrillar proteins were marked on the standard line according to their molecular weight and assigned a gel relative mobility value. According to this procedure eight major myofibrillar protein bands were identified in our samples as shown in Table 8. Figure 18 illustrates the scanning of a gel with the major protein bands showing different peaks. Relative concentration of these proteins in the soluble phase were calculated from the area under the band peaks in Figure 18. These values are shown in Figures 19 and 20 as a function of tumbling time.

It is important to note that after 60 minutes of tumbling the relative concentration of the high molecular weight proteins (myosin heavy chain; M-line and C-protein; α-actinin; and tropomyosin) are higher in the soluble phase of the meat tumbled without vacuum than in the meat tumbled under vacuum. The case of the myosin band is particularly important since this major myofibrillar protein is primarily responsible for

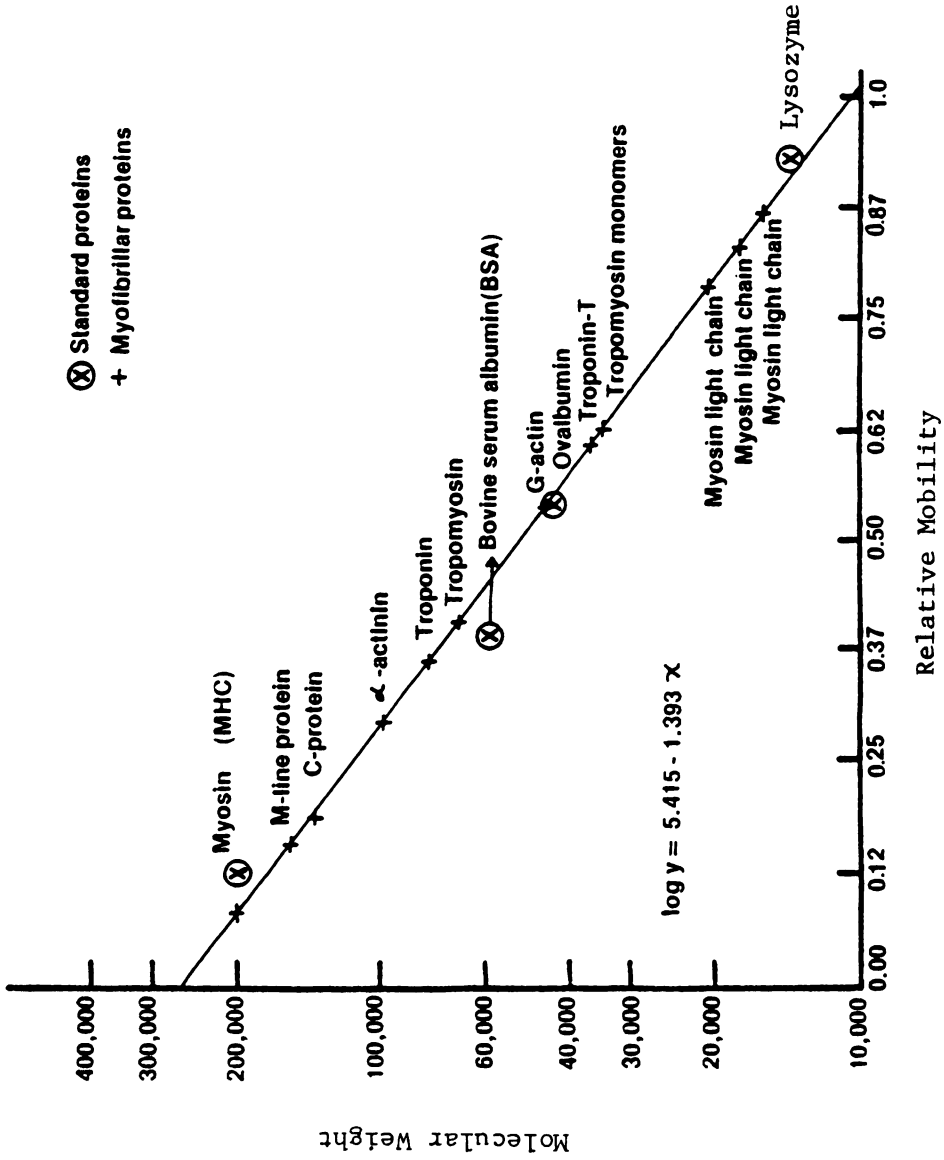


Fig.17 Standard protein mix in SDS-PAGE as a function of molecular weight and relative mobility.

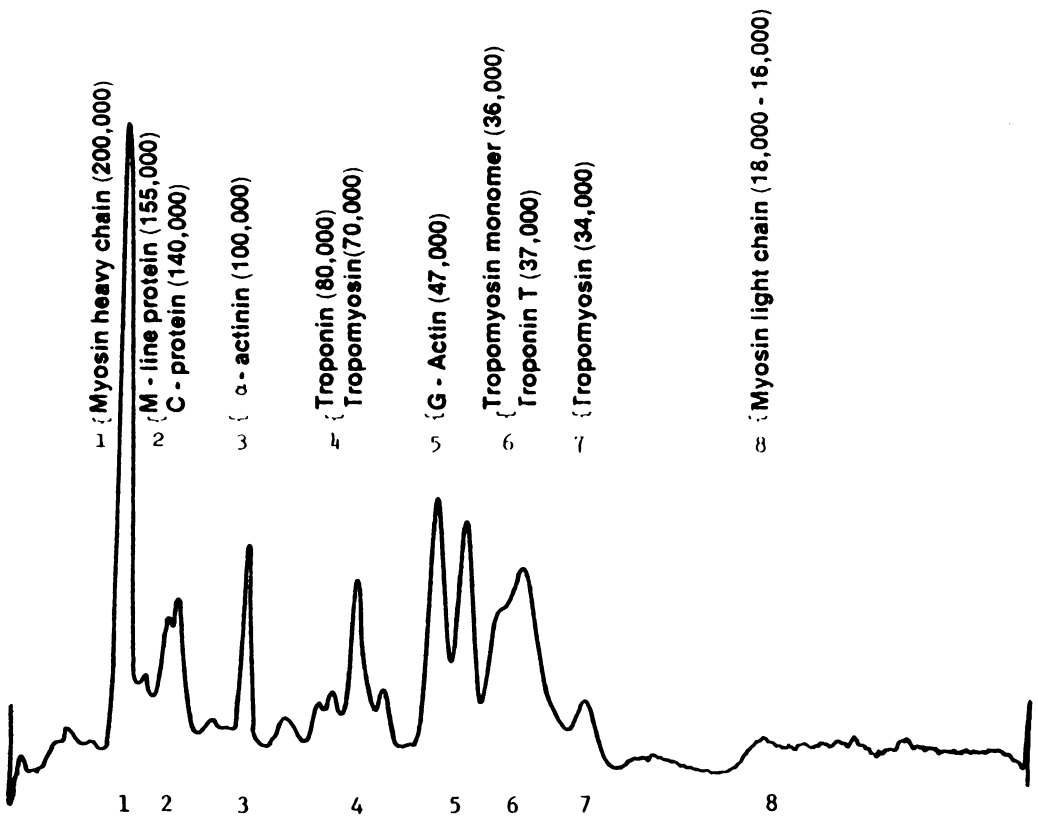


Figure No. 18 Scanning of a SDS-PAGE gel with the major bands assigned to 8 of the most common myofibrillar proteins.

Table 8 - Relative mobility of the major myofibrillar protein bands identified on SDS - PAGE.

Myofibrillar proteins	Molecular weight (daltons)	Relative mobility of the band
Myosin heavy chain (MHC)	200,000	0.10
M-line protein and C-protein	140,000 to 155,000	0.16
α - actinin	100,000	0.29
Tropomyosin complex	70,000	0.40
G - actin bond	46,000	0.54
Troponin-T and Tropomyosin monomer (36,000)	36,000 to 37,000	0.61 to 0.62
Tropomyosin monomer (34,000)	34,000	0.64
Myosin light chains (MLC)	16,000 to 18,000	0.81

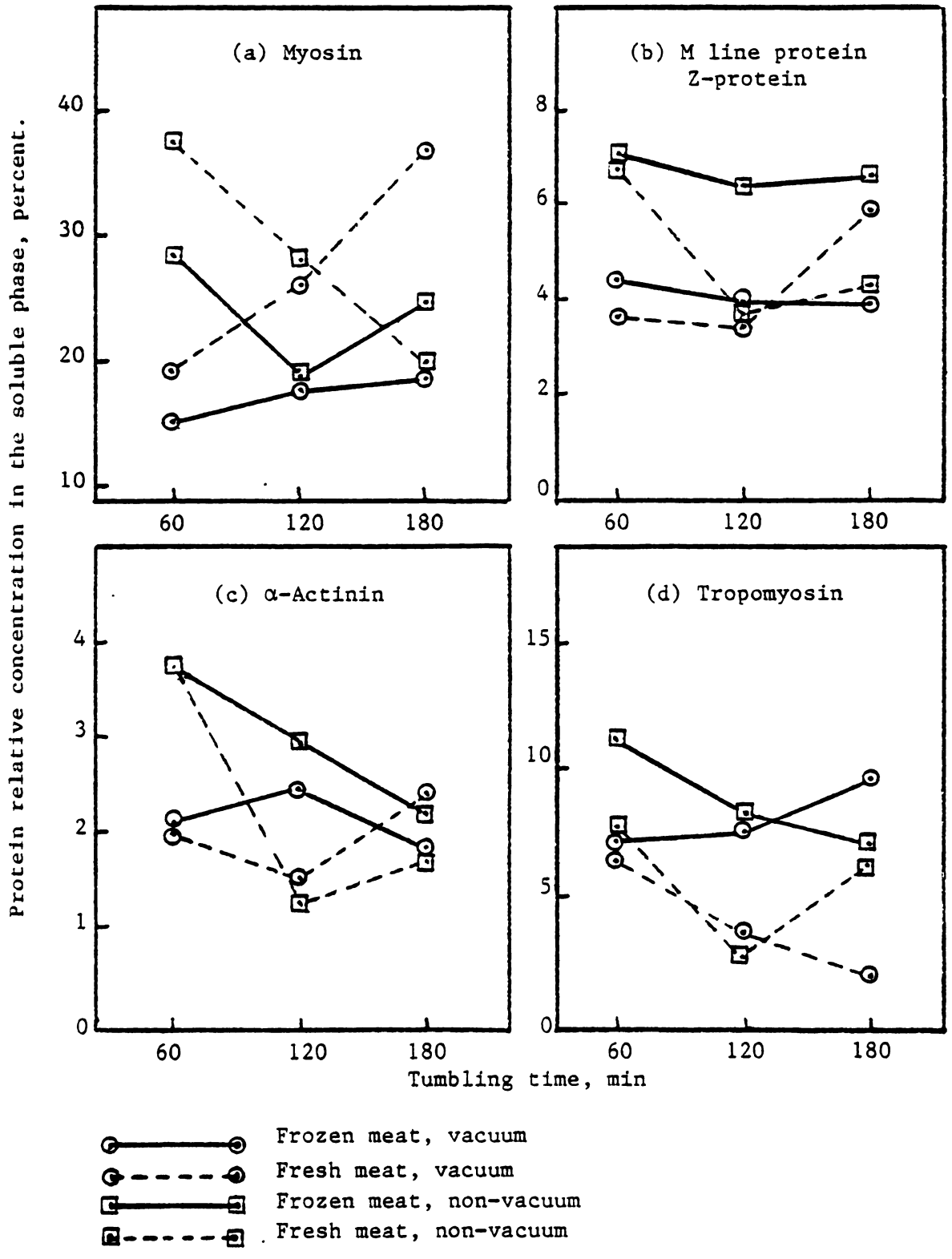


Figure 19 - Relative concentration of Myosin (a); M-line protein and Z-protein (b); α-actinin (c); and Tropomyosin complex (d) in the exudate soluble phase as a function of tumbling time.

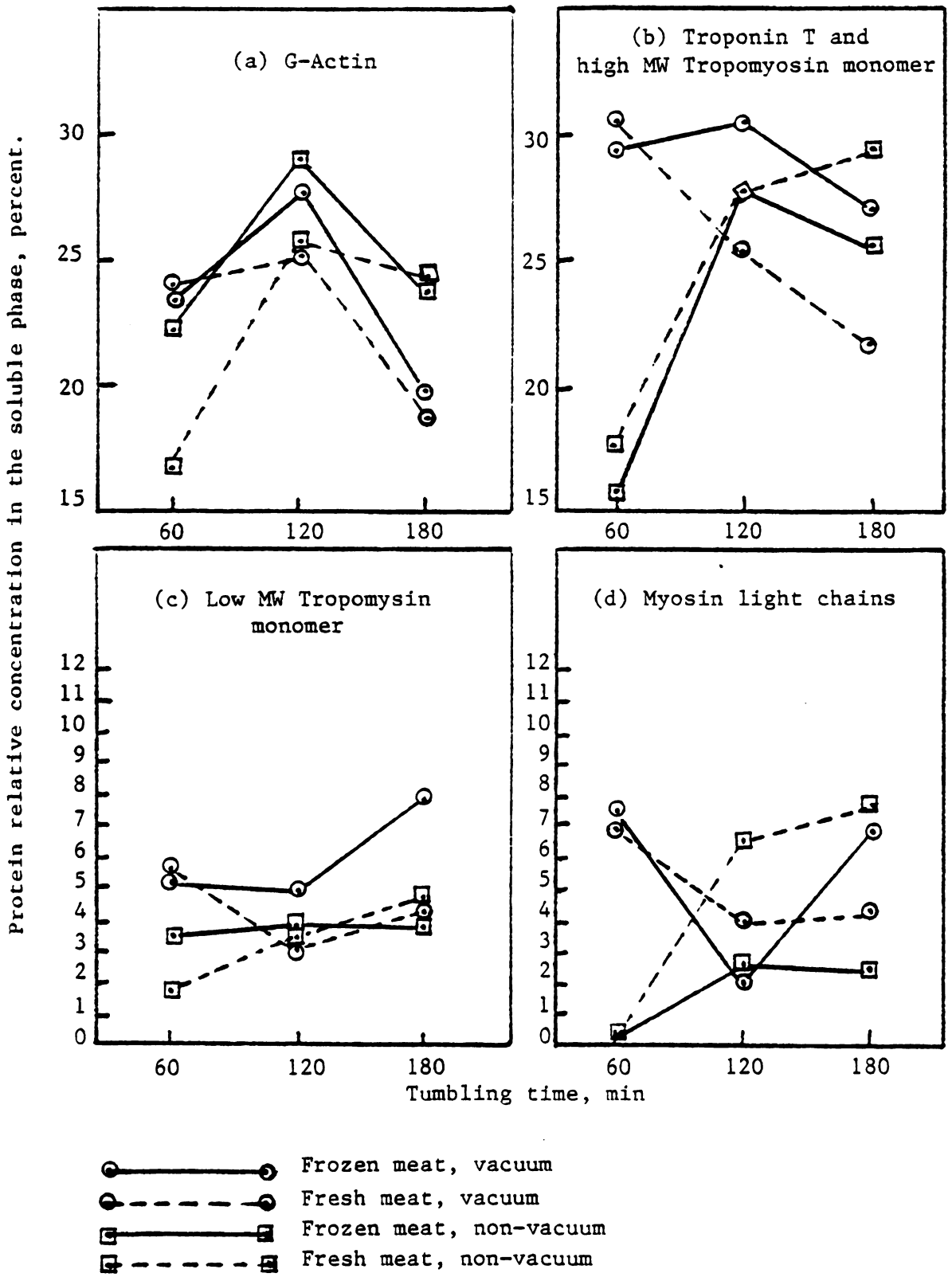


Figure 20 - Relative concentration of G-actin (a); Troponin-T and high MW Tropomyosin monomer (b); Low MW Tropomyosin monomer (c); and Myosin light chains (d), in the exudate soluble phase as a function of tumbling time.

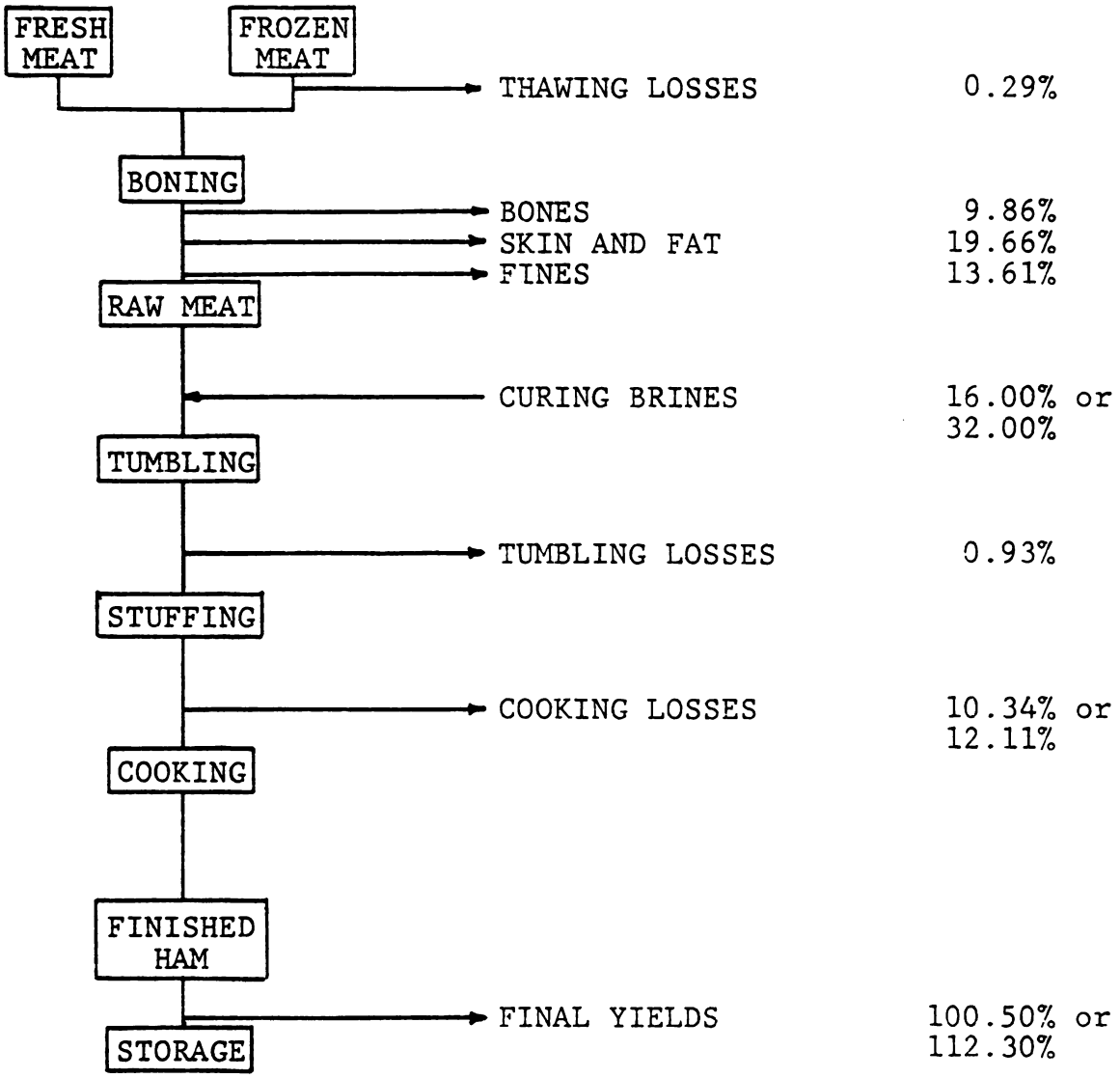
the binding properties in this type of sectioned and formed product (Hegarty, 1963). Statistical analysis showed a significant effect of the condition of the meat and pressure during tumbling on relative myosin concentration in the soluble phase (Appendix C-11). After 60 minutes tumbling myosin relative concentration was significantly higher ($P \leq 0.01$) in both the fresh and frozen meats tumbled without vacuum than in the same meats tumbled under vacuum (Figure 19a). In the system with fresh meat tumbled under vacuum only after 180 minutes tumbling did the level of myosin reach a value comparable to that for the fresh meat tumbled 60 minutes without vacuum (Figure 19a). This situation with myosin is quite similar to the other three high molecular weight proteins (Figures 19b, 19c, and 19d), which probably indicates that the use of vacuum with short periods of tumbling did not contribute to the extraction of myosin and the other high molecular weight myofibrillar proteins. Low molecular weight myofibrillar proteins (G-actin; troponin-T and tropomyosin nonomer [36,000]; tropomyosin monomer [34,000]; and myosin light chains) showed an opposite pattern of extraction. After 60 minutes tumbling under vacuum fresh and frozen meat tended to show higher relative concentrations of these low molecular weight myofibrillar proteins than in the system tumbled without vacuum (Figures 20a, 20b, 20c and 20d).

According to these results, after a short period of tumbling (60 minutes) high molecular weight myofibrillar proteins are higher in the exudate of the meat tumbled without

vacuum than in that of the meat tumbled under vacuum (Figure 19). At the same time low molecular weight myofibrillar proteins are higher in the exudate of the meat tumbled under vacuum than in that of the meat tumbled under no vacuum (Figure 20). This pattern of protein extraction was not apparent after 120 minutes and 180 minutes tumbling. These observations suggest that the use of vacuum during tumbling does not necessarily contribute to the extraction of myofibrillar proteins. Furthermore, the use of vacuum at the end of a tumbling operation rather than throughout the whole process of tumbling may be more advantageous for myosin extraction.

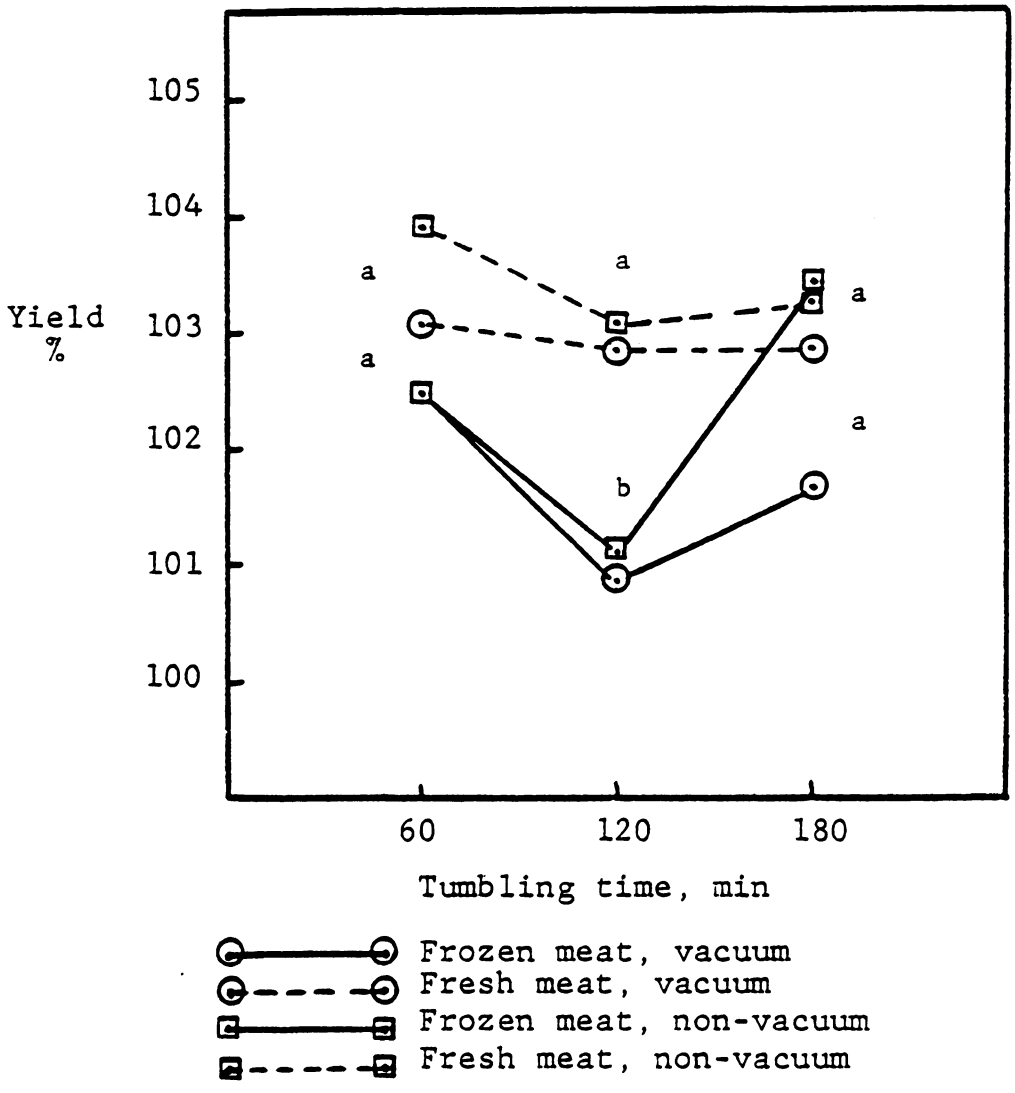
Parameters Related to the Final Product

Figure 21 shows processing steps affecting final processing yield of hams. Pork meat injected 16% and 32% with cure brine showed average processing yields of 100.5% and 112.3%, respectively. Figure 22 shows the effect of tumbling time on actual ham yields. Statistical analysis for yields showed a significant effect ($P<0.01$) of condition of the meat (Appendix C-12). Although there is a trend for better performance of fresh meat over frozen meat in terms of yield (Figure 22), at only 120 minutes level of tumbling time this effect was statistically significant ($P\leq0.01$). This difference in yield may occur because the water-holding capacity of fresh meat appears to be better than that of frozen meat. According to Kramlich *et al.* (1973) federal meat inspection regulations recognize three ham categories depending on the



Note: Final yields calculated based on actual processing losses.

Figure 21 - Processing factors affecting final yields in the process of manufacturing boneless hams.



Note: Pairs of points belonging to the same meat condition with different letters within the same tumbling time are significantly different ($P \leq 0.01$).

Figure 22 - Percent conversion of pork meat into boneless ham as a function of tumbling time. Yields calculated from actual processing losses.

amount of added substance remaining in hams after processing. Added substance refers to water and salt present in the cured product in excess of the normal amount occurring in the uncured product. This control is exercised through calculation based on chemical analysis. The following formula is used for yields: estimated yield = % moisture + % salt - k x % protein + 100; (Kramlich et al. 1973). The protein multiplier or k factor is an average figure representing the approximate ratio of moisture to protein. For smoked hams this factor is 3.79. Table 9 shows the yield of the hams obtained in this study as calculated according to the procedure followed by federal inspection.

Table 9a - Estimated yields of hams as calculated by Federal inspection procedures using 3.79 as k factor.

Tumbling time (min.)	Estimated yields according to Fed. inspection				
	16% pumping				32% pumping
	Vacuum		Non Vacuum		Vacuum
	Fresh	Frozen	Fresh	Frozen	Fresh
60	107.8[2]	99.6[1]	93.4[1]	98.2[1]	116.1[3]
120	101.8[2]	103.5[2]	97.8[1]	101.5[2]	113.8[3]
180	97.7[1]	100.4[2]	102.9[2]	95.4[1]	120.7[3]

[1]Fully cooked hams with no label restrictions

[2]Fully cooked "water-added" hams (According to Federal inspection)

[3]Hams not eligible for sale.

No labeling restrictions are imposed for those hams with estimated yields equal or lower than 100%. Those hams with added substance up to 10% are labeled "water added" hams and those with added substance over 10% are ineligible for sale. according to Federal labeling restrictions (USDA, 1979b). Our results show that 50% of the hams pumped 16% brine should be classified as regular hams (no labeling restrictions) and 50% should be classified as water added hams. No appreciable effect of processing treatments on estimated yields, as calculated according to Federal inspection, was observed in this study (Table 9). Hams pumped 32% with brine showed estimated yields between 113.8% and 120.7% and they fall in the category of not legal hams.

Cooking losses during thermal processing averaged 10.7% with a range from 10.0% to 12.4%. No significant differences due to main effects and/or interactions were observed (Appendix C-13). As expected, cooking losses for the meat injected 32% with brine were significantly higher ($P<0.01$) than those for the meat injected 16% (Figure 23). According to Federal inspection regulations the hams processed in this study are fully cooked or ready-to-eat hams because they were cooked to an internal temperature over 64.5°C (68°C actually).

Figures 24a and 24b show nitric oxide pigments content and percent conversion (the fraction of the total pigments converted into nitric oxide pigments), respectively, as functions of tumbling time. From this figures it can be noted that processing treatment did not drastically affect

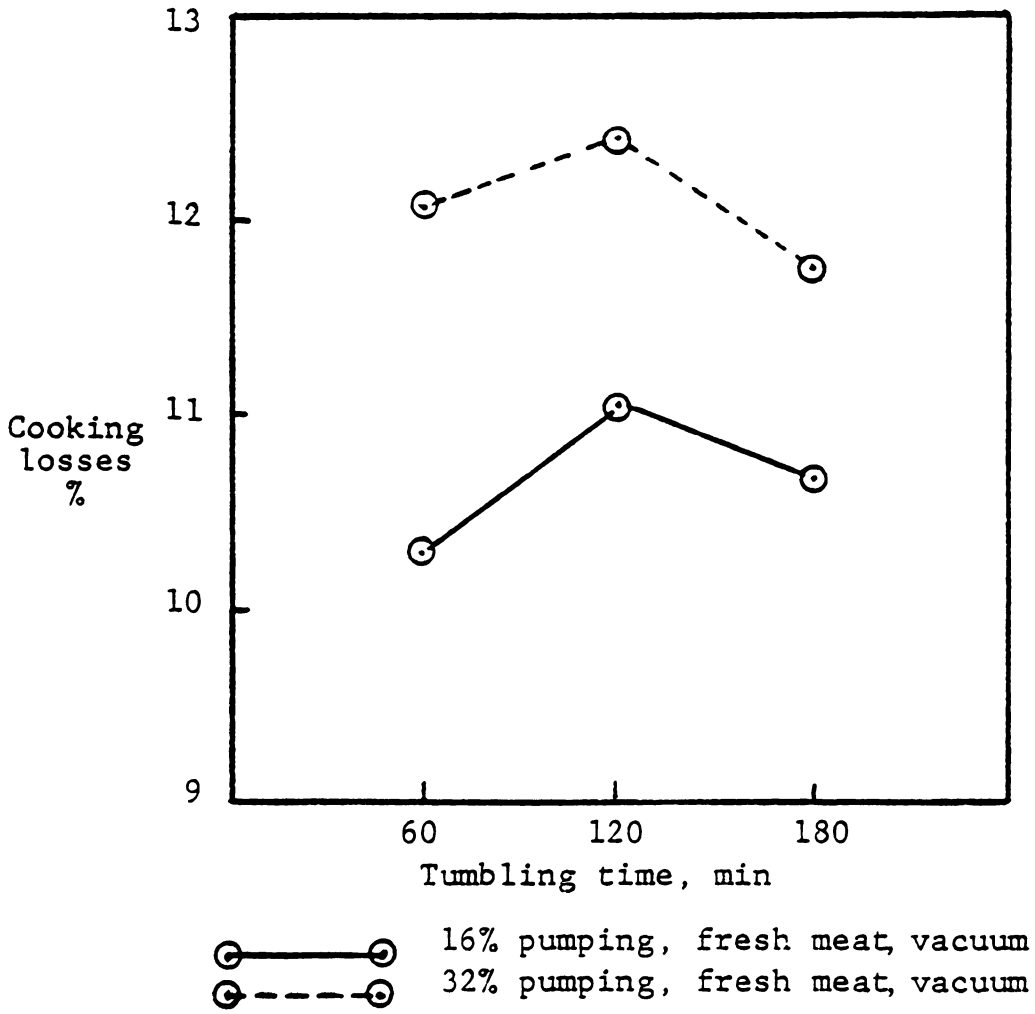


Figure 23 - Cooking losses (%) of the meat as a function of tumbling time and pumping level.

the content of nitric oxide pigments content and pigment conversion in the meat. This is probably due to the multiple needle stitch pumping system used in this study to inject the muscles, which gives a relatively high initial concentration of the cure inside the meat. Tumbling time produced a slight increase in nitric oxide pigments and pigment conversion in the meat tumbled without vacuum. This observation agrees with results reported by Krause et al. (1978b). These authors found a significant improvement in internal color of hams tumbled for 18 hours over hams tumbled for 3 hours. The effect of tumbling on the rate and uniformity of diffusion of curing ingredients probably accounts for the color development. The use of vacuum during tumbling, however, did not improve nitric oxide pigment levels and/or pigment conversion. Furthermore, the meat tumbled without vacuum showed higher levels of both nitric oxide pigments and pigment conversion than that tumbled under vacuum after 180 minutes (Figures 24a and 24b). Although no statistical analysis was possible for these parameters the results tend to indicate that vacuum during tumbling does not have a beneficial effect on pigment conversion and nitric oxide pigments in the meat. No noticeable effect of brine pumping level on nitric oxide pigments or pigment conversion was observed (Figure 25).

Figure 26 shows L, a and b color parameters for ham slices as measured by the Hunter color meter. Although a significant effect ($P \leq 0.01$) of tumbling time on L, a and b color parameters was shown in the statistical study

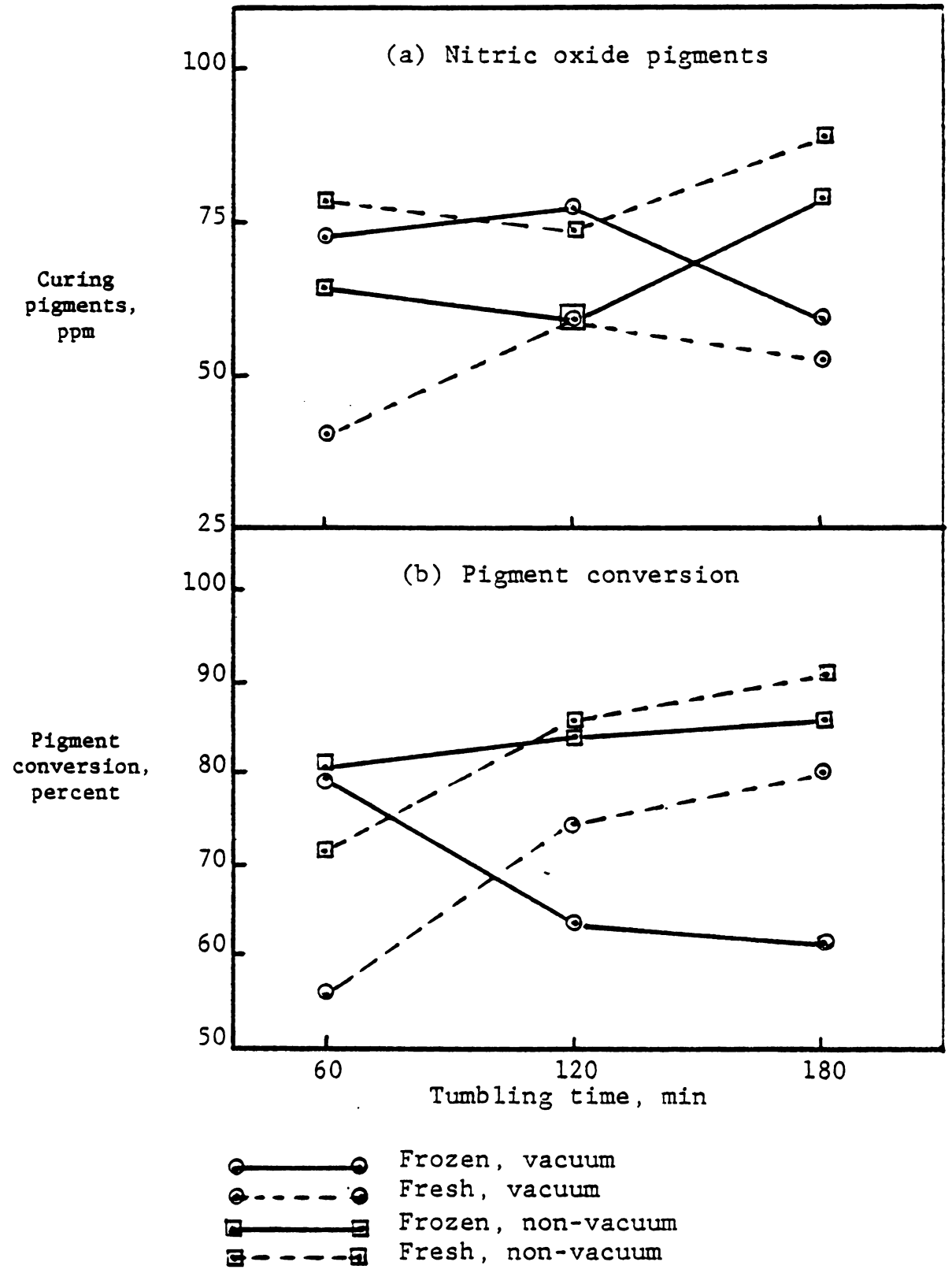


Figure 24 - Nitric oxide pigment content (a) and percent pigment conversion (b) in hams as a function of tumbling time.

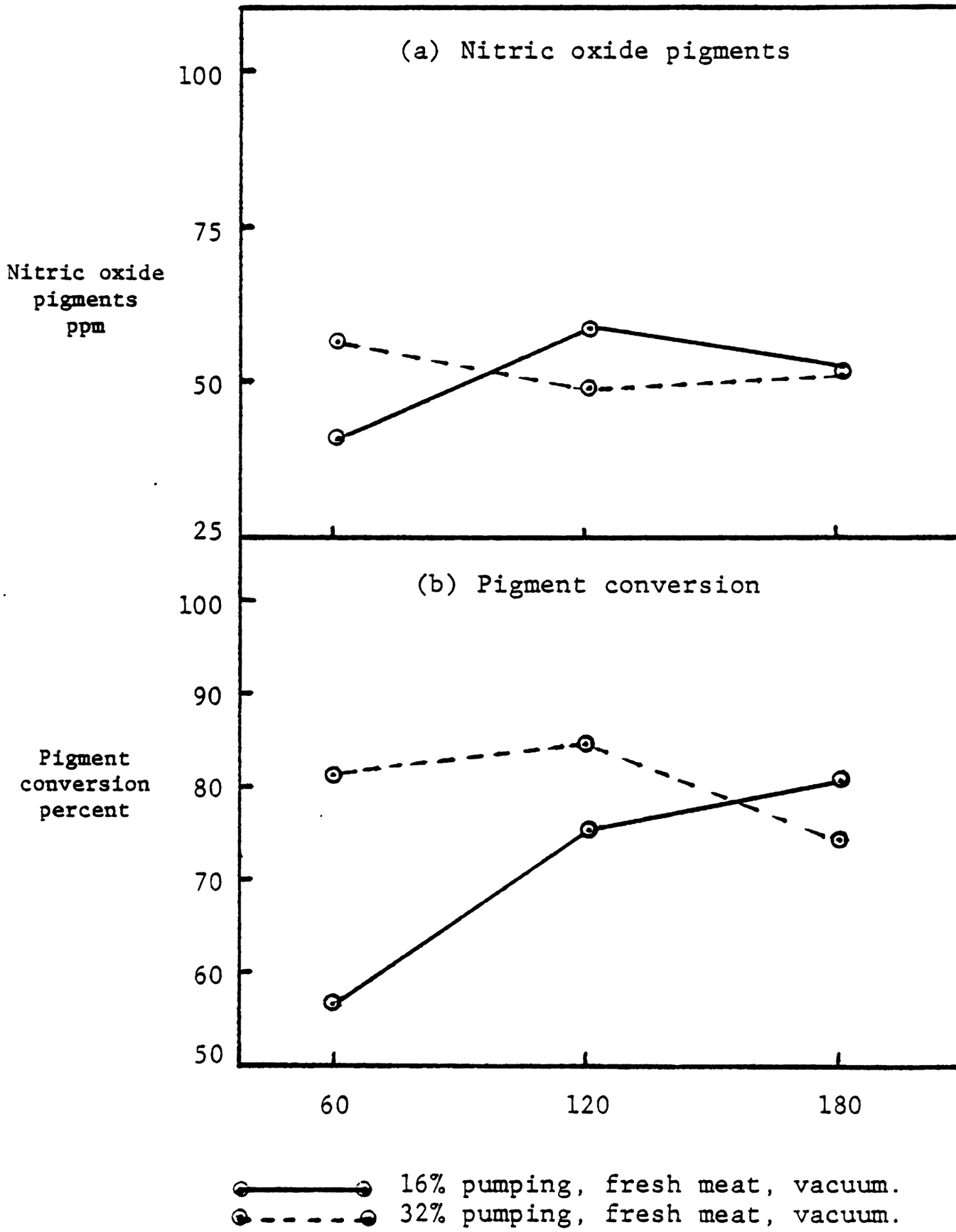


Figure 25 - Nitric oxide pigments (a) and percent pigment conversion (b) as a function of tumbling time and pumping level.

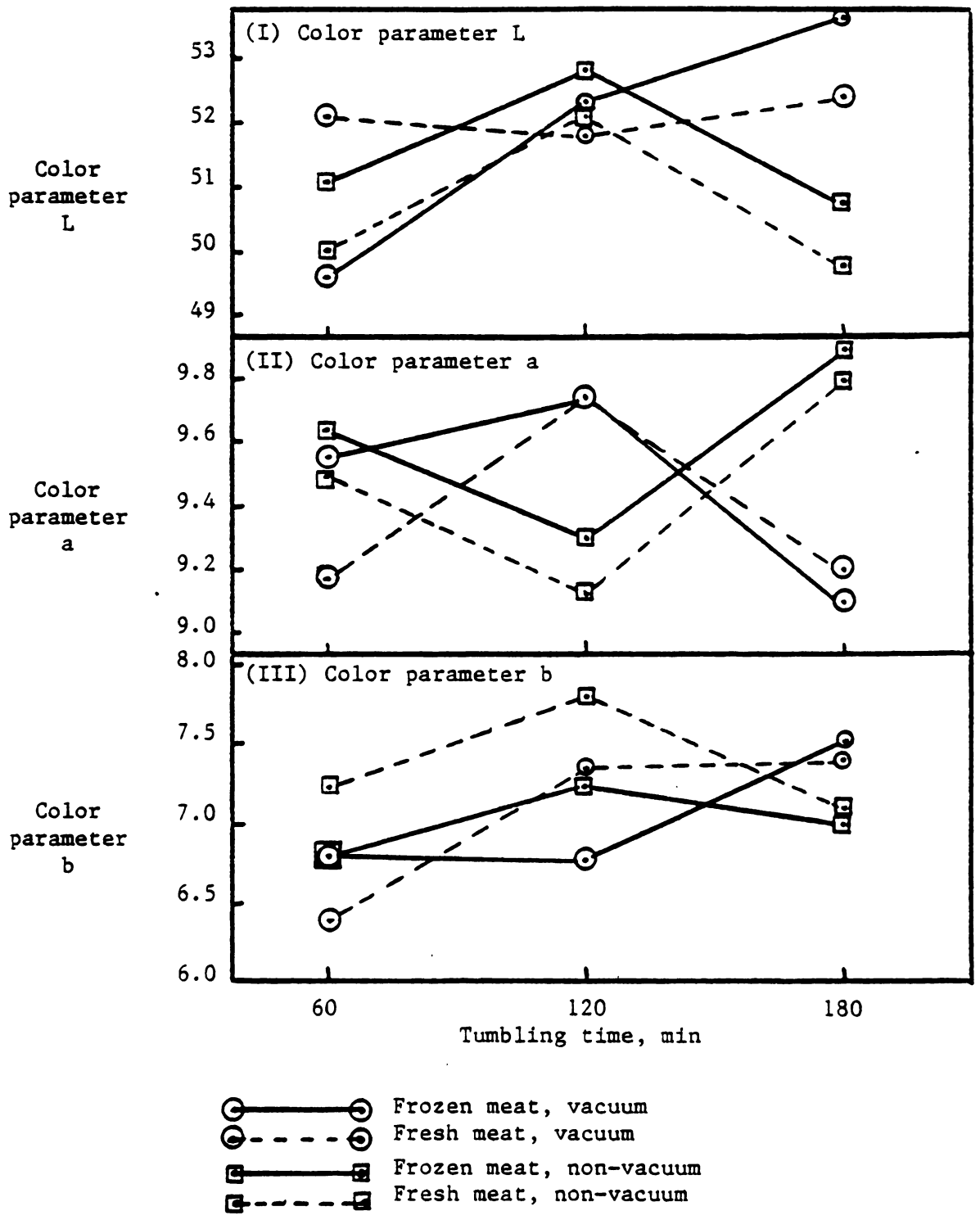


Figure 26 - Color parameter L (I); a (II) and b (III) in the slices as a function of tumbling time.

(Appendices C-14; C-15; and C-16), no trends were evident in the study of the interactions shown in Figures 26(I); 26(II), and 26(III). No relationship between this color determination and the level of nitric oxide pigments discussed above was found either. The main limitation of the assessment of color in the ham by this technique is, of course, the relatively large variability in color intensity from one type of muscle to another within the same ham piece.

Results from the microscopy study are shown in the next series of microphotographs. Figures 27 to 29 show the effect of tumbling on the muscular fiber arrangement in a transversal cut through the tissue. This effect goes from a state in which the fibers are quite ordered, showing circular sections characteristic of intact fresh muscle, and with very little exudate material around them after 60 min. tumbling (Figure 27); to a state in which considerable amount of soluble protein can be seen around the fibers, with increased spacing between fibers and some degree of cell disrupture, after 120 min. tumbling (Figure 28); and to a state in which the fibers have lost their circular shape to the transversal cut, with large spaces filled by protein exudate, air bubbles and/or fat globules (Figure 29). These pictures are quite similar to those reported by Rejt et al. (1978), for massaged porcine bicep femoris muscles. However the presence of exudate material among the fibers is much more evident in the pictures shown in this study than those by Rejt et al. (1978). A similar pattern of fiber

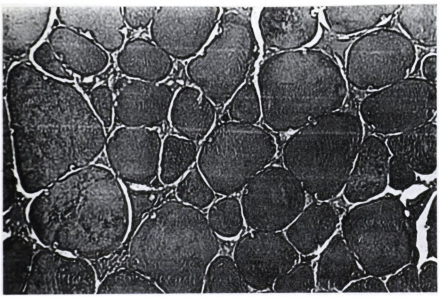


FIGURE 27. Microphotograph of the cross section of bicep femoris fibers in ham from fresh meat, vacuum, 60 minutes tumbling (X80).

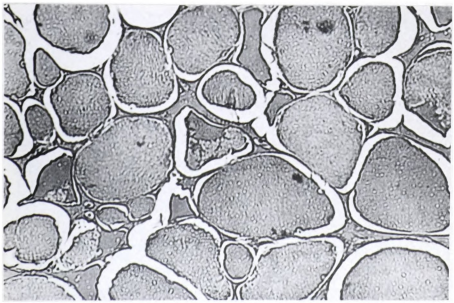


FIGURE 28. Microphotograph of the cross section of bicep femoris fibers in ham from fresh meat, vacuum, 120 minutes tumbling (X80).

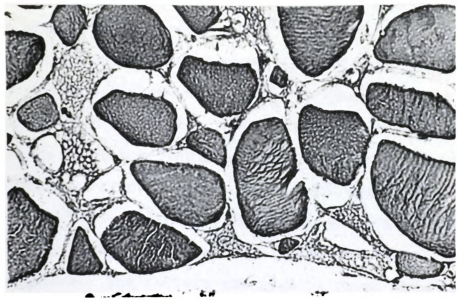


FIGURE 29. Microphotograph of the cross section of bicep femoris fibers in ham from fresh meat, vacuum, 180 minutes tumbling (X80).

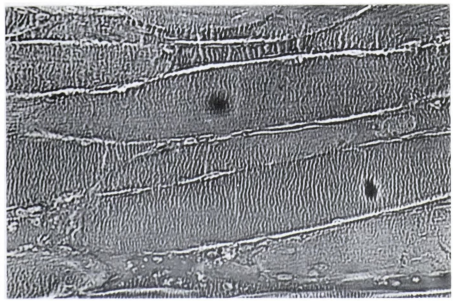


FIGURE 30. Microphotograph of the longitudinal cut of bicep femoris fibers in ham from fresh meat, non vacuum, 60 minutes tumbling (X80).

damage with tumbling time could be observed when the muscle was cut along the direction of the fibers (Figures 30, 31 and 32). It was also evident that tissue fibers damage was greater on the periphery of the muscle chunks than in the interior part of the meat. These observations indicate that the pattern of tissue disruption with tumbling observed in this study can be found in a single chunk muscle which has been tumbled for a relatively short period of time by sampling at different locations from the interior to the periphery of the meat piece. The pattern can also be found in a muscle which is sampled at about the same location but at different times during the tumbling operation. Figure 33 shows a typical seam area in which two chunks of meat bind together. The cross sections of the fibers from one of the meat pieces can be seen in the left side of the picture, separated from the exudate material by some connective tissue layer. Some fat droplets or air bubbles can be seen in the exudate in the lower right corner of the picture. Tumbling seems to have considerably damaged the fibers near the edge of the tissue as the large spacing among them and their irregular shape at the transversal cut demonstrate. Yet, this damage resulted from a processing treatment which used an intermediate tumbling length (120 min.).

The effect of vacuum during tumbling can be seen in Figures 34 and 35. In the former picture the exudate soluble material appears to be quite homogeneous on the edge of the tissue with a few small fat droplets. In the latter picture

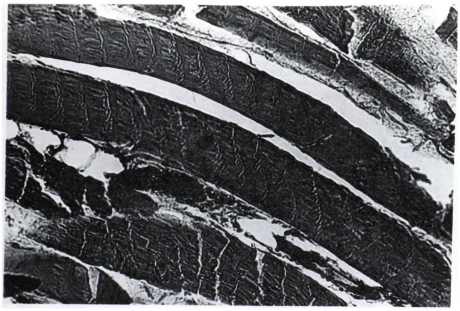


FIGURE 31. Microphotograph of the longitudinal cut of bicep femoris fibers in ham from fresh meat, non vacuum, 120 minutes tumbling (X64).

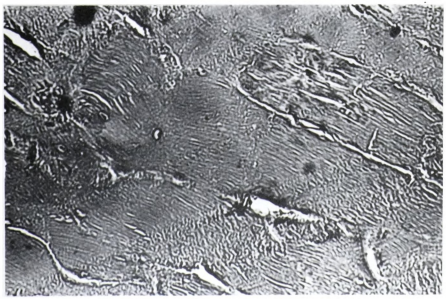


FIGURE 32. Microphotograph of the longitudinal cut of bicep femoris fibers in ham from fresh meat, non vacuum, 180 minutes tumbling (X80).

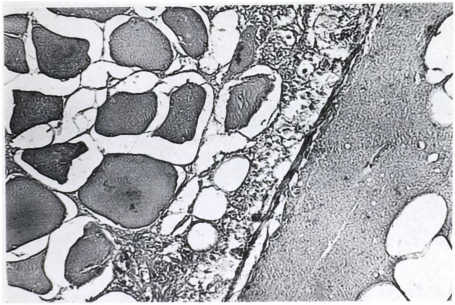


FIGURE 33. Microphotograph of a seam or binding junction area in ham from fresh meat, vacuum and 120 minutes tumbling (X64).

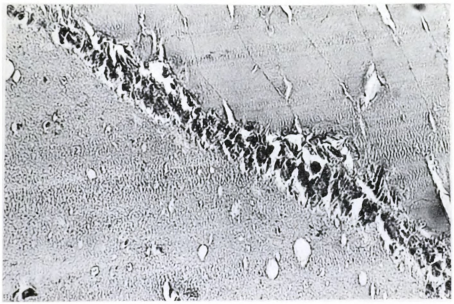


FIGURE 34. Microphotograph of a seam or binding junction area in ham from fresh meat, vacuum, 120 minutes tumbling (X64).

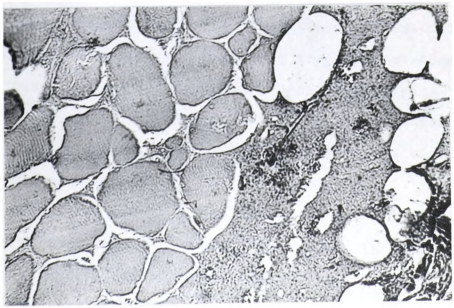


FIGURE 35. Microphotograph of a seam or binding junction area in ham from fresh meat, non vacuum, 120 minutes tumbling (X64).

the exudated soluble material on the left side of the picture shows some air bubbles. Picture 8 belongs to a ham tumbled under vacuum for 120 min. and picture 9 to a ham tumbled without vacuum for 120 min. The use of vacuum during tumbling seems to eliminate much of the air entrapped in the tissue and exudate. This effect will produce hams with a more uniform surface texture and better binding. A foamy exudate interfers with binding (Anonymous, 1981). The effect of the condition of the meat used in this study can be observed in Figures 36 and 37. The former one shows a transversal cut across the fibers of a ham piece from frozen and thawed muscle, and the latter one of a fresh muscle. Both preparations belong to treatments tumbled under vacuum for 120 minutes. The damage produced by the tumbling operation is much more evident in the tissue from frozen and thawed meat than in that from fresh meat. Fibers from frozen and thawed muscle seemed to be more fragile than those from fresh muscle, the reason probably being the physical stress on the fibers during freezing and thawing. No clear differences due to pumping level were observed in the tissue under the light microscope.

Binding strength in ham pieces is shown in Table 10 in the form of tensile strength parameters (g/cm^2) obtained with the Instron universal testing machine. These results indicated that meat tumbled without vacuum binds significantly better ($P \leq 0.01$) than the meat tumbled under vacuum, for processing conditions which included fresh meat tumbled

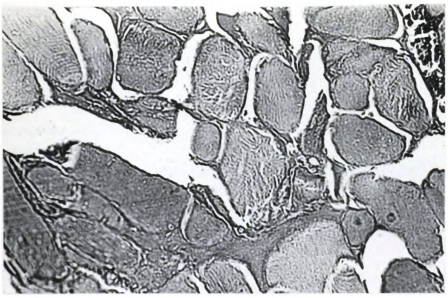


FIGURE 36. Microphotograph of a cross section of bicep femoris fibers in ham from frozen meat, vacuum, 120 minutes tumbling (X80).

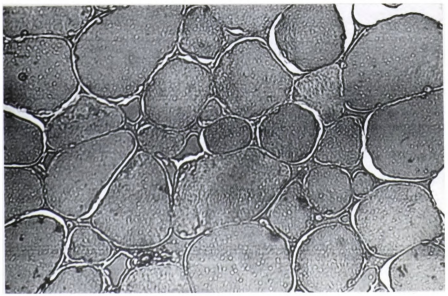


FIGURE 37. Microphotograph of a cross section of bicep femoris fibers in ham from fresh meat, vacuum, 120 minutes tumbling (X80).

Table 10 - Tensile strength values (g/cm^2) measured to separate pieces of hams by the seam or binding area.

TREATMENT IDENTIFICATION NUMBER	PROCESSING FACTOR TESTED	TENSILE STRENGTH g/cm^2
2	Vacuum	$513.4^{a} \pm 11.3$
	vs	
4	Non Vacuum	$922.2^{b} \pm 84.9$
11	Frozen meat	$86.9^{a} \pm 20.3$
	vs	
12	Fresh meat	$155.0^{b} \pm 12.3$
3	Long tumbling	$193.3^{a} \pm 27.5$
	vs	
11	Short tumbling	$86.9^{b} \pm 20.3$
10	16% pumping	$331.7^{a} \pm 42.2$
15	32% pumping	$256.3^{a} \pm 31.2$

[1]Means (within the same processing factor tested) with different superscript letters are significantly different ($P \leq 0.01$).

N = 3

for 180 minutes. Although a better binding was expected with vacuum tumbling, the values of binding for both treatments under comparison are far above those needed for good slicing properties in the ham. According to Theno et al. (1978c), 100 g/cm^2 binding strength is necessary for ham rolls to exhibit acceptable slicing characteristics. Anonymous (1981) reported that with vacuum tumbling a bind of 200 g/cm^2 between muscle sections was considered good for sliced product and was achieved in about four hours. Results in Table 10 also show, as expected, that fresh meat bound significantly better than frozen meat, longer tumbling bound significantly better than short tumbling and 16% pumping better than 32% pumping. It is important to note, however, that this physical determination involves a series of factors which may lead to erroneous measurements or interpretation of the results. One such factor is the difficulty to take the sample from the finished hams. It is hard to localize seams or junction areas in highly trimmed pieces of muscles like the ones used in this study. Sometimes the direction of the fibers on one side of the seam runs parallel to the seam line which makes it very easy to tear apart the meat rather than separate apart the chunks of meat, when the Instron is used. Another factor which may lead to erroneous results is the fact that there are natural seams between muscles which can be mistaken in the final product for protein seams between two individual chunks of meat. In this case the values of tensile strength will be misleadingly

lower or higher depending on the density of the connective tissue between muscles. Finally, there are several muscle components in a ham piece with different intrinsic strength or tenderness. Very tender muscles like the semi membranous can be easily ruptured during the tensile strength determination of the bonding of meat pieces.

Table 11 shows the overall appearance of ham slices by visual inspection. According to these results the color distribution in ham slices from meat tumbled without vacuum was significantly more uniform than that in those from meat tumbled under vacuum. This unexpected result might be due to the great variability in color within some ham slices. Since various types of muscles may be present in a same ham slice the rate of cure penetration and/or the rate of color development is probably different from one muscle type to another. Some characteristics of muscle type such as firmness, fat content and connective tissue content may effect the rate of cure penetration. Moreover, some muscles in pork ham present different proportions of white and red fibers with the consequent difference in pigment level available to react with the cure. Red muscle fibers have a higher myoglobin content, more lipid and higher activity of oxidative enzymes than do white fibers. Lee et al. (1976) found lower residual nitrite in cured meat made from white muscle than that in meat from red muscle. These authors reported that the cause of this phenomena was the low pH of white muscle. No significant differences were observed for

Table 11 - Evaluation of the overall appearance of ham slices by a visual inspection panel.

Treatment ID number	Processing factor tested	Characteristic evaluated, expressed as a preference ratio[1]		
		COLOR Uniform/ Non Uniform	SURFACE TEXTURE No defects/ defects	EXTRANEOUS MATERIAL Absence/ Presence
1	Vacuum	0/12*	2/10	9/3
	vs			
3	Non vacuum	6/6	2/10	5/7
5	Frozen	5/7	8/4	3/9
	vs			
6	Fresh	3/9	2/10	4/8
2	Long tumb.	6/6	7/5	0/12*
	vs			
10	Short tumb.	4/8	4/8	7/5
6	16% pump.	3/9 *	2/10	4/8
	vs			
14	32% pump.	11/1	3/9	5/7

[1] Ratios with an asterisk mark within the same processing factor tested are significantly different ($P<0.01$).

surface texture and presence of non-lean material in the ham slices from meat tumbled with or without vacuum (Table 11). Condition of the meat did not significantly affect color, texture or presence of non-lean material in the ham slices. Moreover, according to the panelists, tumbling time did not affect color and surface texture of ham slices. Short tumbling time (60 minutes) however, produced a significantly higher ($P<0.05$) presence of non-lean material, such as fat and connective tissue. The meat pumped to 32% showed a color uniformity that was significantly higher ($P<0.05$) than that pumped to 16%. No significant differences were detected for surface texture and presence of non-lean material in the meat tumbled 16% and 32%. It should be noticed, however, that the panel failed to detect surface texture differences between the meat tumbled with and without vacuum. Probably, the most evident organoleptic characteristic of the hams obtained in this study was the different surface texture of the hams tumbled under vacuum and no vacuum. The use of vacuum produced hams with a very uniform and homogeneous surface texture; seams or binding joints between chunks of meat were very hard to localize in these products and the whole piece of ham had the appearance of an intact muscle product. When the meat was tumbled without vacuum hams showed a fine porosity at the seam areas and in some muscle or tissue area. In other words, the effect of air bubbles elimination by vacuum was usually apparent on the final product upon slicing the hams.

Table 12 shows the binding strength of ham pieces as evaluated by the taste panel. No significant differences were detected at this point as consequence of tumbling time and pressure during tumbling. Frozen meat bound significantly stronger than fresh meat, a situation opposite to that found with the use of the Instron, above. Sixteen percent pumping produced hams which bound significantly better than those pumped 32% brine, which agree with the results obtained by the objective evaluation of binding using the Instron (Table 10).

It should be noted that values presented in Table 12 represent 24 observations per factor tested (a twelve persons panel judging the same treatment samples in two sessions). Although the group of people participating in this ham quality evaluation was supposed to be a semi-trained panel high variability in the scoring was observed. Scores from the first session did not correlate well with those from the second session. This fact indicates that taste panel evaluation of binding strength in ham pieces is a quite subjective estimation of the force necessary to separate pieces of meat at the binding junction or seam line. Among the factors involved in this problem are the difficulty in selecting and preparing samples, the difference, in binding at different points in the same seam or junction line, the way the panelist pulls the pieces of meat apart, the judgment by the panelist of the binding strength, etc.

Table 13 indicates the values of tenderness of ham

Table 12 - Evaluation of binding strength between pieces of meat in a ham slice by semi-trained panelists.[1]

Coding of treatments	Factor tested	Panelist preference for binding strength: A stronger than B	B stronger than A	Cannot tell the difference
A = treatment 1 B = treatment 3	Vacuum vs Non Vacuum	10[a]	11[a]	3
A = treatment 5 B = treatment 6	Frozen vs Fresh	14[a]	4[b]	6
A = treatment 2 B = treatment 10	Long tumbling vs Short tumbling	7[a]	11[a]	6
A = treatment 6 B = treatment 14	16% pumping vs 32% pumping	16[a]	5[b]	3

[1]Values in the same row with different superscript letters are significantly different ($P \leq 0.05$).

Table 13 - Evaluation of meat tenderness for ham slices by tast panel.[1]

Coding of treatments	Factor tested	Panelist preference for tenderness		
		A more tender than B	B more tender than A	Cannot tell the difference
A = treatment 2 B = treatment 4	Vacuum vs Non Vacuum	15[a]	6[b]	3
A = treatment 7 B = treatment 8	Frozen vs Fresh	16[a]	1[b]	7
A = treatment 1 B = treatment 9	Long Tumbling vs Short Tumbling	11[a]	9[a]	4
A = treatment 6 B = treatment 14	16% pumping vs 32% pumping	10[a]	9[a]	5

[1]Values in the same line with different superscript letters are significantly different ($P \leq 0.05$)

slices as judged by a taste panel. According to these results the meat tumbled under vacuum produced hams significantly more tender ($P \leq 0.05$) than that tumbled without vacuum. These results agree with those found by Rejt et al(1978). These authors reported that vacuum massaged meat showed higher tenderness and lesser cooking loss than non-massaged meat. In this study, frozen meat produced hams significantly more tender than fresh meat. Overall rating of frozen meat by taste panel was equal or better than fresh meat. These observations are substantiated by the results of estimated yields (Table 9) and cooking losses (Page 39) which show no significant effect of condition of the meat. According to the taste panel tumbling time and pumping level did not significantly effect the tenderness of ham slices. Although tenderness of the meat is a quality attribute relatively easy to evaluate by mouth feeling, the intrinsic difference in tenderness from one muscle type to another within a same piece of ham may produce some variation in the response by panelists.

SUMMARY AND CONCLUSIONS

The primary objective of this study was to determine the effects of tumbling time, pressure during tumbling, condition of the meat and brine pumping level on the nature of the exudate after tumbling and the quality parameters of sectioned and formed meats.

Fully cooked boneless hams were manufactured as a model system for the experiment. Four sources of variation were considered in this study: (1) tumbling time (60, 120 and 180 minutes); (2) pressure during tumbling (vacuum and non vacuum); (3) condition of the meat (fresh meat and frozen and thawed meat); and (4) brine injection level (16% and 32% pumping). The meat system was analyzed at four different stages during the process of ham manufacture: (a) the raw meat sample was collected from the trimmed pork muscles just before brine injection and it was analyzed for moisture, fat, protein and lipid oxidation; (b) the tissue sample was collected from the core of the meat chunks, after tumbling, and analyzed for moisture, fat, protein, lipid oxidation, salt and nitrite; (c) the exudate sample, also collected after tumbling, was anlayzed for moisture, fat, protein, lipid oxidation, salt, nitrite, soluble phase volume, protein in the soluble phase and protein composition of the

soluble phase; (d) the ham sample was collected from the finished product and analyzed for moisture, fat, protein, lipid oxidation, salt, nitrite, color distribution, tensile strength, taste panel and microscopic structure of the meat.

Results indicated that protein and fat are extracted with tumbling at different rates, with protein being extracted gradually with tumbling time and fat being extracted mainly at the beginning of tumbling. Protein from fresh meat is extracted with more difficulty than from frozen meat. The use of vacuum does not affect protein and fat extraction.

Although the meat system remained relatively free of lipid oxidation throughout the process, the results indicated that tumbling time and absence of vacuum during tumbling increase lipid oxidation, with the effect being more evident with frozen meat.

After pumping of the brine into the meat nitrite and salt are retained better by fresh meat than frozen meat. Frozen meat tends to absorb much of the cure during tumbling. No effect of vacuum on cure distribution was observed.

The soluble phase extracted from the exudate varied in viscosity with protein content. Small volumes of soluble phase were collected from exudates with high protein content, the amount of total protein being similar for all the treatments under study. Since high myosin contents in the exudate after tumbling are associated with good binding characteristics in the final product the effect of processing treatments is particularly important. The results of this study suggest

that the use of vacuum during tumbling does not contribute to the myosin extraction. Furthermore, with short tumbling (60 minutes) myosin is extracted more easily by tumbling without vacuum. The results also show that the effect of tumbling time on myosin extraction is not conclusive and further research in this area is suggested.

Results related to the final product show that hams pumped 16% with brine are not affected, in terms of yield, by tumbling time and the use of vacuum during tumbling. Fresh meat shows slightly better yields than frozen meat. According to Federal regulations about 50% of the hams pumped 16% in this experiment should be labeled "water added hams". Meat pumped 32% with brine produces hams "not eligible for sale" since they contain more than 10% added substance.

Nitric oxide pigment content and pigment conversion in the hams tumbled without vacuum were higher than in those tumbled under vacuum. However, this difference was not evident when the product was assessed by Hunter color parameters.

Results from the microscopic study show a pattern of increased cell disrupture in the muscle tissue with tumbling time. However, the same pattern of fiber damage can also be observed going from the interior parts to the peripheral parts of the tissue in a single muscle chunk tumbled for a short time. Fibers from frozen meat showed more damage after tumbling than those from fresh meat. The use of vacuum during tumbling eliminated presence of small air bubbles

in the exudate.

Binding strength determinations by the Instron instrument show that treatments without vacuum produced hams which bind better than those from treatments with vacuum. However, binding values for both treatments were highly acceptable for slice-ability characteristics in the ham. No differences in binding due to vacuum effect were detected by the taste panel. Tumbling time does not affect binding strength, according to both the objective and subjective evaluations used in this experiment. Frozen meat binds better than fresh meat, according to the taste panel, but not according to the objective evaluation with the Instron. Although the results show some discrepancies between the subjective and objective evaluation of binding strength as affected by tumbling time, pressure during tumbling and condition of the meat the effect of pumping level is the most evident one. Hams with 16% pumped brine bind significantly better than those pumped 32%.

Color distribution in hams from meat tumbled without vacuum is more uniform than that from meat tumbled under vacuum. However, tenderness of the meat was better in the hams from meat tumbled with vacuum than that from meat tumbled without vacuum.

From the results summarized above it can be concluded that:

(1) Tumbling allowed for more economical usage of added cure substances producing hams of generally

good acceptance by consumers and panelists.

(2) Either fresh or frozen and thawed pork showed to be suitable for this type of processing.

(3) Although protein increased with tumbling time in the exudate, hams with highly acceptable characteristics could be produced with tumbling times as short as 60 minutes (four hours in the tumbler).

(4) The use of vacuum during tumbling improved the overall appearance of the final product primarily by elimination of air bubbles from the exudate. Vacuum did not contribute to extraction of myosin and nitric oxide pigment development in the product. Vacuum should be used in the later stages of the tumbling cycle to improve surface texture of the meat.

(5) When tumbling procedures are used, percent pumping showed to be a critical factor on quality characteristics of the final product. Sixteen percent pumping produced hams of good acceptance characteristics. However, 32% pumping produced hams ineligible for sale, due to the excess moisture retained with poorer slicing and binding properties, although the finished product exhibited acceptable color, flavor and texture.

APPENDIX A

Taste Panel Score Sheets

APPENDIX A

APPENDIX A-1: Score sheet for the evaluation of ham slices by visual inspection.

INSTRUCTIONS

In this part of the panel, you are requested to evaluate the overall appearance of 15 ham slices just by visual inspection. You should concentrated on three types of defects: color uniformity (not color intensity or color differences from one piece of muscle to another); surface texture (presence of holes, air pockets or brine pockets); and presence of non-muscle material (connective tissue lines or fat accumulation).
You are asked to stop by each sample displayed on the table and evaluate the three characteristics before going on the the next sample.
Mark your decision on the logo sheet with a ✓.

	COLOR UNIFORMITY		SURFACE TEXTURE		NON-MUSCLE MATERIAL	
Sample No.	Good distribution	Non uniform	No defects	Presence of defects	No appreciable	Presence of white material

APPENDIX A-2: Score sheet for the evaluation of binding strength and ham tenderness.

HAM TASTE PANEL

Date_____

1. Evaluation of the binding strength.

In this part of the test compare the binding strength of the two pieces of meat inside each plate separately.

Pull apart the meat piece by using either your fingers or by using the two forks. Mark with a ✓ the corresponding square.

Plate 1	_____ stronger than	_____	[_____]
	_____ stronger than	_____	[_____]
	_____ is not different than	_____	[_____]
Plate 2	_____ stronger than	_____	[_____]
	_____ stronger than	_____	[_____]
	_____ is not different than	_____	[_____]
Plate 3	_____ stronger than	_____	[_____]
	_____ stronger than	_____	[_____]
	_____ is not different than	_____	[_____]
Plate 4	_____ stronger than	_____	[_____]
	_____ stronger than	_____	[_____]
	_____ is not different than	_____	[_____]

2. Evaluation of ham tenderness.

In this part of the test compare the tenderness of ham pieces separately in each plate. Chew both ham samples in a plate before making your decision. Mark with a ✓ the corresponding square.

APPENDIX A-2: (Continued)

Plate 1	_____ more tender than _____	[_____]
	_____ more tender than _____	[_____]
	_____ not different than _____	[_____]
Plate 2	_____ more tender than _____	[_____]
	_____ more tender than _____	[_____]
	_____ not different than _____	[_____]
Plate 3	_____ more tender than _____	[_____]
	_____ more tender than _____	[_____]
	_____ not different than _____	[_____]
Plate 4	_____ more tender than _____	[_____]
	_____ more tender than _____	[_____]
	_____ not different than _____	[_____]

APPENDIX B

Chemical Analysis

APPENDIX B-1. Protein content in the meat system as effected by processing treatments. (N=3)

Sample type	Tumbling time (min)	PROTEIN, %				Pooled standard error
		Vacuum		Non-Vacuum		
		Fresh	Frozen	Fresh	Frozen	
Tissue	60	18.45	18.98	17.97	15.92	
Tissue	120	18.41	17.60	18.63	17.87	± 0.30
Tissue	180	18.05	16.61	19.07	19.35	
Exudate	60	11.78	13.52	11.39	12.28	
Exudate	120	13.20	12.58	12.64	13.96	± 0.11
Exudate	180	14.31	13.44	14.63	13.69	
Ham	60	18.15	20.11	20.38	20.30	
Ham	120	19.64	19.27	20.07	18.87	± 0.22
Ham	180	19.57	19.53	19.16	19.72	

Tumbling time (min)	PROTEIN, %						Pooled standard error
	Tissue		Exudate		Ham		
	16% pump	32% pump	16% pump	32% pump	16% pump	32% pump	
60	18.45	15.77	11.78	9.76	18.15	17.25	± 0.26 (Tissue)
120	18.41	15.59	13.20	10.27	19.64	17.98	± 0.22 (Exudate)
180	18.05	14.76	14.31	11.72	19.57	15.21	± 0.33 (Ham)

APPENDIX B-2. Fat content in the meat system as effected by processing treatments. N=3

Sample type	Tumbling time (min)	FAT, %				Pooled standard error
		Vacuum		Non-Vacuum		
		Fresh	Frozen	Fresh	Frozen	
Tissue	60	5.86	0.99	2.44	3.01	
Tissue	120	2.27	2.80	0.89	0.76	± 0.22
Tissue	180	0.50	1.42	3.22	1.17	
Exudate	60	1.94	3.13	7.32	4.60	
Exudate	120	1.48	1.98	6.55	7.41	± 0.46
Exudate	180	7.16	3.80	2.42	7.49	
Ham	60	4.86	3.39	3.35	5.42	
Ham	120	4.84	4.24	3.67	4.37	± 0.10
Ham	180	2.72	4.34	5.08	4.81	

Tumbling time (min)	FAT, %						Pooled standard error
	Tissue		Exudate		Ham		
	16% pump	32% pump	16% pump	32% pump	16% pump	32% pump	
60	5.86	1.30	1.94	2.93	4.86	4.72	± 0.20 (TISSUE)
120	2.27	1.13	1.48	0.89	4.84	3.44	± 0.28 (EXUDATE)
180	0.50	0.51	7.16	2.40	2.72	3.58	± 0.60 (HAM)

APPENDIX B-3. Moisture content in the meat system as effected by processing treatments. (N=3)

Sample type	Tumbling time (min)	FAT, %				Pooled standard error
		Vacuum		Non-Vacuum		
		Fresh	Frozen	Fresh	Frozen	
Tissue	60	70.04	72.48	72.55	69.10	
Tissue	120	73.81	73.14	73.86	72.72	± 0.25
Tissue	180	74.72	73.45	72.30	73.38	
Exudate	60	74.18	73.08	68.76	72.89	
Exudate	120	72.63	74.60	71.82	71.04	± 0.36
Exudate	180	69.63	72.60	73.47	67.82	
Ham	60	72.44	72.46	72.37	70.75	
Ham	120	71.39	71.64	72.77	72.24	± 0.09
Ham	180	72.28	72.29	71.40	70.42	

Tumbling time (min)	MOISTURE, %						Pooled standard error
	Tissue		Exudate		Ham		
	16% pump	32% pump	16% pump	32% pump	16% pump	32% pump	
60	70.04	75.45	74.18	79.27	72.44	73.76	± 0.31 (Tissue)
120	73.81	74.69	72.63	79.80	71.37	75.16	± 0.33 (Exudate)
180	74.27	77.45	69.63	76.04	73.28	76.12	± 0.10 (Ham)

APPENDIX B-4. TBA number in the meat system as effected by processing treatments. (N=3)

Sample type	Tumbling time (min)	TBA Number (mg malonaldehyde/1000 g sample). Vacuum Fresh	Vacuum Frozen	Non-Vacuum Fresh	Non-Vacuum Frozen	Pooled standard error
Tissue	60	.133	.060	.156	.155	
Tissue	120	.007	.000	.037	.083	± .02
Tissue	180	.239	.125	.101	.164	
Exudate	60	.097	-	.118	.105	
Exudate	120	.052	.015	.053	.096	± .01
Exudate	180	.054	.114	.107	.160	
Ham	60	.089	.013	.093	.108	
Ham	120	.096	.147	.055	.145	± .01
Ham	180	.117	.085	.118	.132	

Tumbling time (min)	TBA Number (mg malonaldehyde/1000 g sample). Tissue 16% pump	Tissue 32% pump	Exudate 16% pump	Exudate 32% pump	Ham 16% pump	Ham 32% pump	Pooled standard error
60	.133	.105	.097	.166	.089	.161	± .03 (Tissue)
120	.007	.060	.052	.055	.096	.059	± .02 (Exudate)
180	.239	.107	.054	.092	.117	.126	± .01 (Ham)

APPENDIX B-5. Salt content in the meat system as effected by processing treatments.(N=2)

Sample type	Tumbling time (min)	SALT, %				Pooled standard error
		Vacuum		Non-Vacuum		
		Fresh	Frozen	Fresh	Frozen	
Tissue	60	1.31	2.07	1.64	2.09	
Tissue	120	1.50	1.75	1.95	2.03	± .03
Tissue	180	1.92	2.00	1.60	1.87	
Exudate	60	1.87	2.07	1.78	2.23	
Exudate	120	1.64	1.75	1.85	1.87	± .07
Exudate	180	1.60	1.71	1.90	1.55	
Ham	60	2.45	2.71	1.93	2.25	
Ham	120	2.23	1.94	2.09	1.93	± .07
Ham	180	2.29	1.87	2.05	2.31	

Tumbling time (min)	SALT, %						Pooled standard error
	Tissue		Exudate		Ham		
	16% pump	32% pump	16% pump	32% pump	16% pump	32% pump	
60	1.31	1.60	1.87	1.83	2.45	2.18	± .05 (Tissue)
120	1.50	1.79	1.64	1.98	2.23	2.17	± .04 (Exudate)
180	1.92	2.07	1.60	1.92	2.29	2.35	± .02 (Ham)

APPENDIX B-6. Nitrite content in the meat system as effected by processing treatments. (N=2)

Sample type	Tumbling time (min)	NITRITE (ppm) Vacuum Fresh	Vacuum Frozen	Non-Vacuum Fresh	Non-Vacuum Frozen	Pooled standard error
Tissue	60	68.29	144.44	90.95	139.91	
Tissue	120	100.01	108.18	109.08	140.81	± 4.65
Tissue	180	121.17	147.16	94.58	101.83	
Exudate	60	126.31	149.88	105.46	171.64	
Exudate	120	130.84	116.30	106.37	139.00	± 1.96
Exudate	180	198.84	122.68	119.97	102.74	
Ham	60	73.73	47.43	14.80	29.30	
Ham	120	27.49	62.85	22.05	36.56	± 1.77
Ham	180	19.33	37.46	37.50	21.15	

Tumbling time (min)	NITRITE (ppm) Tissue 16% pump	Tissue 32% pump	Exudate 16% pump	Exudate 32% pump	Ham 16% pump	Ham 32% pump	Pooled standard error
60	68.29	95.49	126.31	113.62	73.73	25.68	± 2.72 (Tissue)
120	100.01	111.81	130.84	123.59	27.49	51.97	± 1.61 (Exudate)
180	121.17	129.03	198.84	119.96	19.33	44.71	± 1.51 (Ham)

APPENDIX C

Analysis of Variance Tables

APPENDIX C-1. ANOVA table for protein content in the exudate as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

A21 PROT EXUDATE
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	19.509	4	4.877	13.886	.001
A01	.016	1	.016	.044	.835
A02	.580	1	.580	1.652	.211
A03	18.914	2	9.457	26.923	.001
2-WAY INTERACTIONS	10.445	5	2.089	5.947	.001
A01 A02	.258	1	.258	.736	.400
A01 A03	2.729	2	1.364	3.884	.035
A02 A03	7.458	2	3.729	10.616	.001
3-WAY INTERACTIONS	3.069	2	1.534	4.368	.024
A01 A02 A03	3.069	2	1.534	4.368	.024
EXPLAINED	33.023	11	3.002	8.547	.001
RESIDUAL	8.430	24	.351		
TOTAL	41.453	35	1.184		

36 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

APPENDIX C-2. ANOVA table for protein content in the exudate as affected by tumbling time and pumping level.

TUMBLING STUDY 05/28/81
TWO WAY ANALYSIS OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN SIXTEEN

* * * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * * *

A21 PROT EXUDATE
BY A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN
A06 PUMPING 1=16 PERCENT 2=32 PERCENT

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	43.572	3	14.524	95.104	.001
A03	15.221	2	7.611	49.835	.001
A06	28.350	1	28.350	185.641	.001
2-WAY INTERACTIONS	.622	2	.311	2.036	.173
A03 A06	.622	2	.311	2.036	.173
EXPLAINED	44.194	5	8.839	57.877	.001
RESIDUAL	1.833	12	.153		
TOTAL	46.026	17	2.707		

18 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

APPENDIX C-3. ANOVA table for fat content in the exudate as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

A23 FAT EXUDATE
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	73.880	4	18.470	28.364	.001
A01	66.477	1	66.477	102.089	.001
A02	.588	1	.588	.903	.352
A03	6.815	2	3.407	5.233	.013
2-WAY INTERACTIONS	63.013	5	12.603	19.354	.001
A01 A02	5.921	1	5.921	9.093	.006
A01 A03	52.374	2	26.187	40.216	.001
A02 A03	4.718	2	2.359	3.623	.042
3-WAY INTERACTIONS	58.957	2	29.479	45.271	.001
A01 A02 A03	58.957	2	29.479	45.271	.001
EXPLAINED	195.850	11	17.805	27.343	.001
RESIDUAL	15.628	24	.651		
TOTAL	211.478	35	6.042		

36 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

APPENDIX C-4. ANOVA table for fat content in the exudate as affected by tumbling time and pumping level.

TUMBLING STUDY 05/28/81
TWO WAY ANALYSIS OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN SIXTEEN

* * * * * * * * ANALYSIS OF VARIANCE * * * * * * * *

A23 FAT EXUDATE
BY A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN
A06 PUMPING 1=16 PERCENT 2=32 PERCENT

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	49.573	3	16.524	68.600	.001
A03	40.083	2	20.041	83.201	.001
A06	9.490	1	9.490	39.399	.001
2-WAY INTERACTIONS	26.514	2	13.257	55.037	.001
A03 A06	26.514	2	13.257	55.037	.001
EXPLAINED	76.087	5	15.217	63.175	.001
RESIDUAL	2.891	12	.241		
TOTAL	78.978	17	4.646		

18 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

APPENDIX C-5. ANOVA table for moisture content in the exudate as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * ANALYSIS OF VARIANCE * * * * * * * *

A22 MOIST EXUDATE
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	48.704	4	12.176	30.382	.001
A01	29.757	1	29.757	74.250	.001
A02	.590	1	.590	1.473	.237
A03	18.357	2	9.178	22.902	.001
2-WAY INTERACTIONS	30.983	5	6.197	15.462	.001
A01 A02	9.394	1	9.394	23.440	.001
A01 A03	8.831	2	4.415	11.017	.001
A02 A03	12.758	2	6.379	15.916	.001
3-WAY INTERACTIONS	72.530	2	36.265	90.488	.001
A01 A02 A03	72.530	2	36.265	90.488	.001
EXPLAINED	152.217	11	13.838	34.528	.001
RESIDUAL	9.618	24	.401		
TOTAL	161.835	35	4.624		

36 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

APPENDIX C-6. ANOVA table for TBA number in the exudate as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * ANALYSIS OF VARIANCE * * * * * * * *

A24 TBA EXUDATE
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	.036	4	.009	21.342	.001
A01	.011	1	.011	26.697	.001
A02	.001	1	.001	1.296	.267
A03	.018	2	.009	21.811	.001
2-WAY INTERACTIONS	.011	5	.002	5.280	.002
A01 A02	.002	1	.002	4.754	.040
A01 A03	.000	2	.000	.152	.860
A02 A03	.008	2	.004	9.620	.001
EXPLAINED	.047	9	.005	12.399	.001
RESIDUAL	.010	23	.000		
TOTAL	.057	32	.002		

36 CASES WERE PROCESSED.
3 CASES (8.3 PCT) WERE MISSING.

DUE TO EMPTY CELLS OR A SINGULAR MATRIX,
HIGHER ORDER INTERACTIONS HAVE BEEN SUPPRESSED.

APPENDIX C-7. ANOVA table for salt content in the exudate as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * ANALYSIS OF VARIANCE * * * * * * * * *

A25 SALT EXUDATE
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	.464	4	.116	13.168	.001
A01	.047	1	.047	5.320	.040
A02	.049	1	.049	5.523	.037
A03	.368	2	.184	20.915	.001
2-WAY INTERACTIONS	.236	5	.047	5.370	.008
A01 BY A02	.013	1	.013	1.485	.246
A01 BY A03	.019	2	.009	1.071	.373
A02 BY A03	.204	2	.102	11.612	.002
3-WAY INTERACTIONS	.133	2	.067	7.577	.007
A01 BY A02 BY A03	.133	2	.067	7.577	.007
EXPLAINED	.833	11	.076	8.607	.001
RESIDUAL	.106	12	.009		
TOTAL	.939	23	.041		

36 CASES WERE PROCESSED.
12 CASES (33.3 PCT) WERE MISSING.

APPENDIX C-8. ANOVA table for nitrite content in the exudate as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * ANALYSIS OF VARIANCE * * * * * * * *

A26 NITR EXUDATE
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	2766.213	4	691.553	90.094	.001
A01	1657.346	1	1657.346	215.914	.001
A02	35.042	1	35.042	4.565	.054
A03	1073.825	2	536.913	69.947	.001
2-WAY INTERACTIONS	15428.736	5	3085.747	402.002	.001
A01 A02	3683.795	1	3683.795	479.914	.001
A01 A03	3226.917	2	1613.458	210.197	.001
A02 A03	8518.024	2	4259.012	554.851	.001
3-WAY INTERACTIONS	70.943	2	35.472	4.621	.032
A01 A02 A03	70.943	2	35.472	4.621	.032
EXPLAINED	18265.892	11	1660.536	216.330	.001
RESIDUAL	92.111	12	7.676		
TOTAL	18358.004	23	798.174		

36 CASES WERE PROCESSED.
12 CASES (33.3 PCT) WERE MISSING.

APPENDIX C-9. ANOVA table for volume of the soluble phase in the exudate as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

A27 VOL SOL PHASE EXUDATE
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	22.502	4	5.626	27.695	.001
A01	.444	1	.444	2.188	.165
A02	10.240	1	10.240	50.412	.001
A03	14.309	2	7.155	35.223	.001
2-WAY INTERACTIONS	4.162	5	.832	4.098	.021
A01 A02	.490	1	.490	2.412	.146
A01 A03	.030	2	.015	.075	.928
A02 A03	2.294	2	1.147	5.646	.019
EXPLAINED	28.676	9	3.186	15.686	.001
RESIDUAL	2.438	12	.203		
TOTAL	31.113	21	1.482		

36 CASES WERE PROCESSED.
14 CASES (38.9 PCT) WERE MISSING.

DUE TO EMPTY CELLS OR A SINGULAR MATRIX,
HIGHER ORDER INTERACTIONS HAVE BEEN SUPPRESSED.

APPENDIX C-10. ANOVA table for protein in the soluble phase as affected by tumbling *time, pressure during tumbling and condition of the meat.*

TUMBLING STUDY 05/28/81
THREE WAY ANOVA OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

A28 BIU PROT SOL PHASE
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	1715.927	4	428.982	30.630	.001
A01	258.070	1	258.070	18.426	.001
A02	287.734	1	287.734	20.544	.001
A03	1170.122	2	585.061	41.774	.001
2-WAY INTERACTIONS	1743.687	5	348.737	24.900	.001
A01 A02	102.094	1	102.094	7.290	.019
A01 A03	327.291	2	163.645	11.684	.002
A02 A03	1314.302	2	657.151	46.921	.001
3-WAY INTERACTIONS	214.847	2	107.424	7.670	.007
A01 A02 A03	214.847	2	107.424	7.670	.007
EXPLAINED	3674.461	11	334.042	23.851	.001
RESIDUAL	168.065	12	14.005		
TOTAL	3842.526	23	167.066		

36 CASES WERE PROCESSED.
12 CASES (33.3 PCT) WERE MISSING.

APPENDIX C-11. ANOVA table for myosin relative content in the soluble phase as affected by tumbling time, pressure during tumbling and condition of the meat.

05/28/81

TUMBLING STUDY
THREE WAY ANOVA OF EXUDATE
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

A29 MYOSIN
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	385.480	4	96.370	10.392	.001
A01	92.042	1	92.042	9.925	.008
A02	273.375	1	273.375	29.480	.001
A03	20.063	2	10.032	1.082	.370
2-WAY INTERACTIONS	474.155	5	94.831	10.226	.001
A01 A02	49.882	1	49.882	5.379	.039
A01 A03	411.643	2	205.822	22.195	.001
A02 A03	12.630	2	6.315	.681	.525
3-WAY INTERACTIONS	207.903	2	103.952	11.210	.002
A01 A02 A03	207.903	2	103.952	11.210	.002
EXPLAINED	1067.538	11	97.049	10.465	.001
RESIDUAL	111.280	12	9.273		
TOTAL	1178.818	23	51.253		

36 CASES WERE PROCESSED.
12 CASES (33.3 PCT) WERE MISSING.

APPENDIX C-12. ANOVA table for ham yields as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA FOR FINISHED HAM
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

A45 YIELD HAM
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	13.616	4	3.404	4.750	.016
A01	1.602	1	1.602	2.235	.161
A02	7.482	1	7.482	10.440	.007
A03	4.533	2	2.266	3.162	.079
2-WAY INTERACTIONS	3.338	5	.668	.932	.494
A01 A02	.007	1	.007	.009	.925
A01 A03	.516	2	.258	.360	.705
A02 A03	2.816	2	1.408	1.965	.183
3-WAY INTERACTIONS	.906	2	.453	.632	.548
A01 A02 A03	.906	2	.453	.632	.548
EXPLAINED	17.860	11	1.624	2.266	.088
RESIDUAL	8.600	12	.717		
TOTAL	26.460	23	1.150		

36 CASES WERE PROCESSED.
12 CASES (33.3 PCT) WERE MISSING.

APPENDIX C-13. ANOVA table for ham cooking losses as affected by tumbling time, pressure during tumbling and condition of the meat.

05/28/81

TUMBLING STUDY
THREE WAY ANOVA FOR FINISHED HAM
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * ANALYSIS OF VARIANCE * * * * * * * *

A51 B COLOR HAM
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	2.386	4	.597	5.681	.002
A01	.218	1	.218	2.074	.163
A02	.321	1	.321	3.058	.093
A03	1.847	2	.924	8.796	.001
2-WAY INTERACTIONS	2.482	5	.496	4.728	.004
A01 BY A02	.218	1	.218	2.074	.163
A01 BY A03	1.561	2	.780	7.431	.003
A02 BY A03	.704	2	.352	3.352	.052
3-WAY INTERACTIONS	.284	2	.142	1.352	.278
A01 BY A02 BY A03	.284	2	.142	1.352	.278
EXPLAINED	5.152	11	.468	4.461	.001
RESIDUAL	2.520	24	.105		
TOTAL	7.672	35	.219		

36 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

APPENDIX C-14. ANOVA table for L color parameter in hams as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA FOR FINISHED HAM
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

A49 L COLOR HAM
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	23.906	4	5.977	5.603	.002
A01	7.840	1	7.840	7.350	.012
A02	.934	1	.934	.876	.359
A03	15.132	2	7.566	7.093	.004
2-WAY INTERACTIONS	26.547	5	5.309	4.977	.003
A01 A02	3.361	1	3.361	3.151	.089
A01 A03	17.052	2	8.526	7.993	.002
A02 A03	6.134	2	3.067	2.875	.076
3-WAY INTERACTIONS	7.127	2	3.564	3.341	.052
A01 A02 A03	7.127	2	3.564	3.341	.052
EXPLAINED	57.580	11	5.235	4.907	.001
RESIDUAL	25.600	24	1.067		
TOTAL	83.180	35	2.377		

36 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

APPENDIX C-15. ANOVA table for a color parameter in hams as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA FOR FINISHED HAM
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

A50 A COLOR HAM
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	.252	4	.063	.664	.623
A01	.123	1	.123	1.289	.267
A02	.123	1	.123	1.289	.267
A03	.007	2	.004	.038	.963
2-WAY INTERACTIONS	2.489	5	.498	5.240	.002
A01 A02	.002	1	.002	.026	.872
A01 A03	2.375	2	1.188	12.500	.001
A02 A03	.112	2	.056	.588	.563
3-WAY INTERACTIONS	.102	2	.051	.535	.592
A01 A02 A03	.102	2	.051	.535	.592
EXPLAINED	2.843	11	.258	2.721	.020
RESIDUAL	2.280	24	.095		
TOTAL	5.123	35	.146		

36 CASES WERE PROCESSED.
0 CASES (0 PCT) WERE MISSING.

APPENDIX C-16. ANOVA table for b color parameter in hams as affected by tumbling time, pressure during tumbling and condition of the meat.

TUMBLING STUDY 05/28/81
THREE WAY ANOVA FOR FINISHED HAM
FILE MEAT (CREATION DATE = 05/28/81)
SUBFILE ELEVEN MELEVEN

* * * * * * * * A N A L Y S I S O F V A R I A N C E * * * * * * * *

A46 COOKING LOSSES HAM
BY A01 PRESSURE LEVELS 1=VAC 2=NON VAC
A02 CONDITION 1=FRESH MEAT 2=FROZEN MEAT
A03 TIME 1=60 MIN 2=120 MIN 3=180 MIN

* *

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F	SIGNIF OF F
MAIN EFFECTS	6.774	4	1.693	4.134	.025
A01	1.915	1	1.915	4.675	.052
A02	1.581	1	1.581	3.859	.073
A03	3.277	2	1.639	4.000	.047
2-WAY INTERACTIONS	.806	5	.161	.393	.844
A01 BY A02	.126	1	.126	.308	.589
A01 BY A03	.167	2	.083	.204	.818
A02 BY A03	.513	2	.256	.626	.551
3-WAY INTERACTIONS	.111	2	.055	.135	.875
A01 BY A02 BY A03	.111	2	.055	.135	.875
EXPLAINED	7.691	11	.699	1.707	.186
RESIDUAL	4.916	12	.410		
TOTAL	12.607	23	.548		

36 CASES WERE PROCESSED.
12 CASES (33.3 PCT) WERE MISSING.

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