

THE EFFECT OF VARIOUS BINDERS AND MEATS
ON THE PALATABILITY AND PROCESSING
CHARACTERISTICS OF BOLOGNA

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ABSTRACT

THE EFFECT OF VARIOUS BINDERS AND MEATS ON THE PALATABILITY AND PROCESSING CHARACTERISTICS OF BOLOGNA

by Elbert Harold Rongey

Various binders are added to bologna type sausage for the purpose of enhancing water retention during processing and improving the flavor, texture, tenderness, and juiciness of the product.

The objectives of this investigation were to study the effects of non-fat dry milk, fermented non-fat dry milk, soya grits, phosphates, and type of meat on the palatability and processing characteristics of bologna. These were accomplished by conducting a series of comparison tests. The first included four levels of non-fat dry milk, 3.5, 10, 15, and 20 percent, based on the weight of the finished product. The second comparison included 3.5 and 10 percent non-fat dry milk where each was used with regular binding, low fat, high fat, and low binding (included 25 percent pork hearts) meat formulations. The third comparison utilized the four meat formulations for comparing the effects of 10 percent soya grits, 10 percent non-fat dry milk, and 4.7 ounces of phosphate (a mixture of 25% crossed linked potassium Kurrol's salt plus 75% sodium tetrapyrophosphate) per 100 pounds of meat. The fourth comparison included tests on bologna and thuringer in which non-fat dry milk, with and without sodium tripolyphosphate, was compared with fermented non-fat dry milk, with and without sodium tripolyphosphate.

The factors evaluated in this investigation included flavor, texture-tenderness, juiciness, yield, heat transfer, shrinkage (7 day), moisture, protein, fat, pH of finished product, color as determined by Munsell Spinning Disks, and tensile strength.

In the first comparison the addition of 3.5 percent non-fat dry milk increased the yield of bologna significantly over that of the control or 20 percent non-fat dry milk treatment. Non-fat dry milk did not influence percent moisture or protein at the levels tested but due to substitution of non-fat dry milk for meat in the formulation, the fat content was influenced significantly at the higher levels.

pH values were increased approximately 0.1 unit by the addition of non-fat dry milk. Color was lighter with higher levels of non-fat dry milk due to dilution of the meat pigment. Tensile strength was increased with 3.5 and 10 percent non-fat dry milk whereas 20 percent resulted in a significant reduction in tensile strength. The flavor was improved most by the addition of 3.5 percent non-fat dry milk, while 10 and 20 percent increased juiciness most and yielded the greatest differences in texture-tenderness. The addition of non-fat dry milk did not influence shrinkage (7 day).

In the second comparison, in addition to confirming observations from the first comparison as regards moisture, protein, shrinkage, and pH, the type of meat did influence the moisture and protein content. The percent fat was influenced significantly by both non-fat dry milk and type of meat. pH varied about 0.2 units between treatments and color was only slightly changed with 10 percent non-fat dry milk. Tensile strength was increased by addition of non-fat dry milk and by the low binding meat formulation. Flavor and texture-tenderness were not influenced with the treatments of this comparison, however, 3.5 percent non-fat dry milk and the low fat formulation reduced juiciness.

In the third comparison, phosphate produced a significantly greater yield than the control. Phosphate, non-fat dry milk, and soya grits did

not differ in their effects on yield. The regular binding and high fat formulations produced greater yields than did low binding or low fat formulation. Addition of phosphate resulted in a significantly greater shrink than was produced with either non-fat dry milk or soya grits. The type of meat did not influence shrinkage.

The protein content was higher where soya grits or low fat was employed. The type of meat had a significant influence upon the fat content. Phosphate and soya grits increased the pH by 0.1 to 0.4 units. A higher fat content yielded a lighter color and pork hearts or low fat yielded a redder color. Soya grits produced a more yellow color. The addition of phosphate, non-fat dry milk, soya grits, or low fat meat formulation increased the tensile strength, with phosphate showing the greatest effect.

Soya grits, at the level tested, yielded bologna with a less desirable flavor than all other treatments. The low binding formulation yielded a more desirable flavor than that having a high fat content. Juiciness was significantly reduced by the addition of soya grits over that of other binders. Phosphate treated bologna received significantly lower texture-tenderness values than the control as did the low fat meat formulation compared with regular binding and high fat treatments. For thuringer in the fourth comparison, the addition of non-fat dry milk, with or without phosphate, resulted in a greater yield compared with fermented non-fat dry milk, with and without phosphate. Addition of fermented non-fat dry milk resulted in greater shrinkage. While the moisture content was not influenced by these treatments, the protein content was greater where fermented non-fat dry milk was added. The percent fat was not significantly influenced by the variables of this comparison.

The addition of either fermented non-fat dry milk or non-fat dry milk plus starter culture resulted in decreased pH values. Color differ-

ences between treatments were only slight. Tensile strength was significantly reduced by addition of fermented non-fat dry milk. The flavor of bologna was less desirable and juiciness was increased by the addition of fermented non-fat dry milk. Addition of 7.5 percent fermented non-fat dry milk plus phosphate yielded bologna that was significantly more tender than bologna containing 3.5 percent non-fat dry milk plus phosphate.

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By
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INTRODUCTION

The origin of sausage is difficult to trace, but the Romans are known to have enjoyed sausage over 2,000 years ago. The word sausage was derived from the Latin "salsus", meaning salted, which would indicate that the use of cured meats may have been used in its original preparation. The first sausages are believed to have been of the dry variety as they could be stored longer than fresh meats.

Jensen (1949), in reviewing the history of sausage, stated that it is one of the oldest forms of processed foods and was developed independently by many "peoples of antiquity." In general, the many varieties of sausage were named after the town or specific area in which they were developed. Each variety became known for its particular flavor, coarseness of grind, type of casing or method of tying. This has been attributed to the fact that limited spices were available for any particular area and, in general, the production of sausage was carried out by an individual or family. Each had his own secret spice formulation and specific processing techniques. These were, and some still are, handed down through the generations. Sausage making developed as an art and due to the secretive methods and general lack of scientific applications, it has remained an art rather than a science.

Sausage is the product resulting from mixing comminuted beef and pork with various spices, with or without curing ingredients, and stuffed into natural or artificial casings. It may be cooked and/or smoked or prepared as fresh sausage. Other meats such as veal, lamb, and mutton are frequently employed, as well as various binding materials.

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that proper record-keeping is essential for transparency and accountability, particularly in financial matters. The text outlines various methods for organizing and storing data, including digital databases and physical filing systems. It also mentions the need for regular audits and reviews to ensure the integrity and accuracy of the information.

2. The second section focuses on the role of communication in achieving organizational goals. It highlights the importance of clear and concise communication channels, both internally and externally. The text discusses the benefits of regular meetings, reports, and updates, as well as the potential pitfalls of poor communication. It encourages the use of technology to facilitate communication and collaboration among team members.

3. The third part of the document addresses the issue of resource management. It discusses the importance of identifying and allocating resources effectively to support the organization's mission and vision. The text provides guidance on how to prioritize tasks and projects, manage budgets, and ensure that resources are used efficiently. It also touches on the importance of human resources, including recruitment, training, and employee development.

4. The final section discusses the importance of risk management and compliance. It outlines the various risks that an organization may face, including financial, operational, and reputational risks. The text provides strategies for identifying, assessing, and mitigating these risks, as well as the importance of staying up-to-date with relevant laws and regulations. It emphasizes the need for a proactive approach to risk management and compliance to ensure the long-term success and sustainability of the organization.

Sausages are generally classified into three major groups; namely, fresh, cooked and/or smoked, and dry sausages. Fresh sausages are those that are uncured and not cooked during processing. The second classification includes sausages of the frankfurter-bologna type. The dry varieties would include thuringer, salami, and summer sausage and are mainly of Italian or German origin.

To improve the binding qualities of sausage where lower quality meats are used, the industry has found that cereals, phosphates, and non-fat dry milk are desirable binders and they are commonly used where state or federal regulations permit. According to the Meat Inspection Division (M.I.D. 1960), the use of cereal flours, vegetable flours, starchy vegetable flours, non-fat dry milk, dry milk, and soya flour, individually or collectively, is limited to 3.5 percent of the finished product. In addition, with reference to final composition, the amount of moisture may not exceed four times the protein plus ten in cooked sausages.

The objectives of this study were: 1. to establish the binding effects of non-fat dry milk on the processing and quality characteristics of bologna when used at levels exceeding M.I.D. limits; 2. to determine the effect that type of meat, with reference to fat content and binding quality, would have on processing and quality characteristics of bologna when three levels of non-fat dry milk were employed; 3. to determine the effects on processing and quality characteristics when various types of meat were used with three different binders in bologna; 4. to study the effects of fermented non-fat dry milk and non-fat dry milk on the processing and quality characteristics of bologna and thuringer.

The significance of this study can be attributed to the fact that many additives find application in sausages, primarily for reducing production cost. The addition of a product(s) to sausages for the purpose of improving quality characteristics, such as nutritional value, with a concomitant reduction of production costs would be desirable.

LITERATURE REVIEW

Effect of Meat Composition as Related to Binding Quality In Sausage. Wilson (1960) reported that for the production of sausage having a uniform quality, one must make the proper selection of meat ingredients. The more important properties of the raw meat ingredients to be considered were binding properties and lean-fat ratio. Different animal tissues show variations in their moisture-to-protein ratio and in their fat-to-lean ratio. Variations occur in water-binding properties of different animal tissues. This characteristic refers to their ability to absorb and retain moisture throughout heat processing. He stated that many of the factors responsible for variations in binding properties of meat are not understood at this time.

Wilson stated that on the basis of commercial use in sausage, meats were classified as "binder" meats or "filler" meats. The binder meats were subdivided into high, medium, and low with respect to their ability to absorb and hold moisture. High binding meats were given as skeletal tissue from beef and include bull meat, chucks, and boneless cow meat. Of intermediate binding were head meat, cheek meat, and lean pork trimmings. A large proportion of fat or non-skeletal (smooth) muscle generally characterized the meats with inferior or low binding qualities. These included regular pork trim, jowls, ham fat, beef briskets, hearts, hanging tenders, weasand meat, and tongue trimmings. Other low binding meats that could be used in limited amounts (approximately 20%, if a satisfactory quality was to be maintained) were ox lips, tripe, pork stomachs, skin, snouts, lips, and

partially defatted pork tissue. These were referred to as filler meats. While the specific factors causing variation in binding properties of meat are not understood, Wilson (1960), considerable work has been conducted investigating the more fundamental principles involved with the water-holding capacity of meat and the influence of this characteristic upon various quality factors.

A series of reports have been published from a study conducted at Ohio State University which dealt with factors affecting or dependent upon the degree of hydration of muscle proteins. These reports included a comprehensive review of earlier work conducted in Germany dealing with this and related problems. Wierbicki, et al., (1954) in reporting on this study, stated that "post mortem tenderization may be a manifestation of the general problem of relation of ions to protein hydration, which is so intimately associated with many food problems involving consumer quality attributes as well as shrinkage in cooking and processing." They suggested that a random diffusion of ions may occur during rigor and change the hydration of the muscle proteins, particularly actomyosin. Protein hydration was clearly related to total ionic strength as well as to types of ions present. They reported that post mortem increases in pH, regardless of reason for this increase, would increase protein hydration and possibly improve tenderness.

They stated that sodium phosphate and other sodium salts have been used to characterize the ionic-protein relationships in red meat which improved tenderness and decreased shrinkage. "A delightful whole "corned" beef of remarkable tenderness was produced" by a ten percent

infusion of whole animals with a 20 percent sodium chloride solution containing sodium nitrate and sodium nitrite. In addition, extensive improvements were observed in water-holding capacity both after freezing and thawing and after cooking. They stated that post mortem intramuscular changes may be due to: "proteolysis, dissociation of actomyosin, or ionic rearrangement to increase the degree of protein hydration." Any or all of these may be involved.

Wierbicki et al., (1956), in a further study, reported that for the study of protein hydration during post mortem aging both pH and ion-protein interrelationships are of significance. Their results showed that in all cases pH shifted away from the isoelectric point (toward alkalinity) of muscle protein and that an increase in water-holding capacity resulted. They concluded that if tenderness is closely related to degree of hydration of the meat proteins as indicated by their results, then tenderness, shrink on cooking, drip on defrosting, and rehydration after dehydration are all based on the water-holding capacity of meat proteins.

Arnold et al., (1956), in a later report, stated that calcium and sodium are released by muscle protein during aging and from the results of their study the total cationic shift was a movement of ions into the meat proteins. One exception in the results was noted, however, As a result of this shift, the proteins acquired a greater positive charge and the authors suggested that the charge on the protein may be the factor responsible for water-binding capacity of fresh meats. They reported that at the isoelectric point, with a net charge of zero on the protein, the hydration of the protein would be

at a minimum. They concluded that, in general, the importance of cations to water-holding capacity and tenderness was related more directly to the combined effect of the ions rather than a specific ion effect. Also, movements of the ions during post mortem aging were believed to have an effect. The theory that the charge on the protein was possibly the factor responsible for water-binding capacity of fresh meats had been discussed earlier by Hamm (1953).

Wierbicki et al., (1957) stated that "shrinkage and water-holding capacity of meat and of processed meats have always been of great concern to meat packers and hotel and restaurant operators." This was primarily from the standpoint of yield of product. A simplified centrifugal method was developed whereby the water-holding capacity of meat could be determined. They applied this technique to study the relationships of temperature of heating, added water, and other factors on the water-holding capacity of meat. They reported that pronounced changes occurred in meat proteins between 40 and 70°C. Between 55 and 70°C., protein hydration was promoted in such a way as to counteract the denaturation effects. Dynamic shifts between meat and "expressed juice" were reported to have involved sodium, potassium, and calcium ions in this range of temperatures.

Briskey et al., (1960) reported on a study that included the relationships of various characteristics with the water-binding properties of eight pork muscles. They noted that four muscles which had lower pH values (as pH approached the isoelectric point) also possessed the greatest percentages of expressible water. These same muscles also contained the greatest concentrations of myoglobin. Winkler (1939)

reported that variations in the ability of muscle tissue to imbibe water as pH changed provided the connecting link in enzymatically aged muscle. Muscle fibers at pH 7.0 were reported capable of absorbing their own volume of water but as the pH was decreased to 6.0, less than 50 percent was absorbed. At pH 5.0 only 25 percent imbibition was observed.

Haurowitz (1955) reported that it is difficult to distinguish between "bound" and "free" water molecules. Binding of water is due, in part, to water molecules combining with body constituents, and partially to mechanical occlusion of water between a lattice of fibrous molecules and membranes. Hashimoto et al., (1959) observed that water-holding capacity in sausage prepared from stored meat samples was affected noticeably by pH of the meat, especially with pH values below 6.0. They concluded that this relationship possibly existed as a result of the pH of the meat approaching the isoelectric point of myosin. According to Lawrie (1958), the protein of muscle is associated with more water at higher pH values and elicits a reduction in the fluid phase of the muscle which gives it a more "close" structure.

Swift and Ellis (1957) stated that binding of moisture in bologna, as determined by shrinkage, was not improved by addition of phosphates when the product was processed to an internal temperature of 150°F. They did observe, however, that when the internal temperature was increased to 160°F., phosphate treated bologna showed less shrinkage than control batches. They concluded that phosphate treated bologna showed a marked increase in relative binding of the sausage components as determined by the effect of phosphate on increasing the tensile strength, or cohesion of meat, in samples of bologna.

Gerrard (1955) reported that the whole secret to success in sausage depends upon standardization. The most variable ingredient is the meat and if one understands meat composition as well as the changes it undergoes during processing, sausage of uniform quality can be more easily produced. He attributed variations of moisture in sausage to the amount of water added with the binder and the amount of water present in the meat used. The latter was considered the most difficult to control. As the fat content increases in meat, the moisture and protein decreases, according to Gerrard. He reported a range of from 75 to 79 percent moisture in fat free muscular tissue.

Swift and Hankins (1954) stated that the percentage of added moisture was not a good measure of moisture added during processing nor of the nutritional quality of the finished product. Swift et al., (1954) reported on the effects of variations in moisture and fat content on the juiciness and tenderness of bologna. They established that both moisture and fat content affected the tenderness and juiciness of bologna. Changes in tenderness and juiciness were influenced more by changes in moisture than fat. They suggested that fat and moisture are, to a certain extent, interchangeable in their effect on the two factors. No variation in flavor was found with the variations in composition employed.

Maroney and Landmann (1959) conducted a study on moisture and fat in fresh meats commonly used in sausage formulations. They reported that positive determinations of protein, moisture, and fat composition of a product can be gained only by chemical analysis. Meats used in sausage preparations were reported to show considerable

variation even when obtained from "identical" lots. They indicated that for calculating the percentage of "added water" to be utilized in sausages, the calculations should be based on the protein content of the finished product rather than on the emulsion formula. The same tissues from different animals varied in moisture content and differences in the ratio of water to protein were reported to vary with age of animal, decreasing as the animals reached "chemical maturity". This was about five months for beef cattle and up to five months for swine. A method was presented for estimating moisture in sausage formulas. Calculations were included for formulations with and without milk powder and similar procedures were presented for the estimation of the percentage fat in the finished product.

Properties of the emulsion. In a recent study conducted by Hansen (1960), an evaluation of some of the basic theories concerning emulsion formation in finely comminuted sausage was presented. He reported that a dispersion of fat globules was produced within the protein slurry during chopping of comminuted sausages. The fat globules are reduced in size as the chopping process continues. He was able to show this by a series of photomicrographs taken at various stages in the chopping operation. In addition, he concluded that the fragments of tough connective tissue formed by preliminary grinding appeared to remain unchanged during chopping. The salt soluble proteins, myosin and actomyosin, were reported to concentrate at the surface of the fat globules and form a stabilizing membrane. It was found that chopping time must be continued for sufficient time to permit formation of a protein matrix enclosing the dispersed fat globules.

It was further reported that if during the chopping operation, any excessive rise in temperature occurred, then the protein matrix could be partially denatured and broken, giving rise to an unprotected fat dispersion which in turn would allow fat separation during smoking and cooking.

Tauber (1957), in discussing theories of sausage emulsions and related problems encountered by sausage makers, stated that the emulsion resulting from comminuting the meat ingredients with ice, salt, and cure is a typical oil-in-water emulsion. The emulsion is a mixture of salt-soluble protein with swollen and disintegrated meat fibers intertwined like a web throughout the sausage mass. There is usually sufficient salt-soluble protein to coat the fat globules contained in the emulsion. The salt-soluble protein coagulates on cooking and entraps the fat particles in a series of protein sacs. In discussing the effect of overchopping, he suggested that the surface area of the fat is increased to the point that sufficient protein is not available for coating the fat and on heating, one can observe formation of fat and/or jelly pockets due to separation. He also reported that even though sufficient protein is available to coat the fat particles, it is possible to have fat and gelatin separation occur by heating the product too rapidly, which ruptures the protein sacs surrounding the fat particles.

Action of binders. The use of binders, or fillers, in the manufacture of sausages has been a common practice in most countries since the early development of such meat items. The binders most frequently employed are cereal flours, non-fat dry milk, phosphates, potato flour,

and in some cases corn flour and gelatin. In the United States, however, the use of phosphates has not been approved for sausages.

Kraybill (1955) and Wilson (1960) reported that the major reasons for adding the so-called binders to sausages are absorption of moisture added during chopping and retaining this moisture throughout processing. Binders may also serve as emulsifying agents between the protein, fat, and moisture of the meat. Other changes believed due to binders are improved color, texture, and flavor. While some, if not all, binders are used to reduce the cost of production, all of them do not have the same effect upon the nutritive value of the finished product.

Effectiveness of Soya Flour as a Sausage Binder. Miller (1958) reported that soya flour does not possess binding characteristics like those of cereal flours, but that it does have good moisture absorbent powers as well as the ability to blend nicely with meats. He pointed out that soya grits differ from soya flour only in the degree of milling. Hale (1945), in reporting on a study concerned with the development of a test for detection of soybean flour in meat products, stated that soybean flour was being used in such products as "artificial bologna" and "cottage loaves". Frank and Circle (1959), working with isolated soybean protein, produced a non-meat bologna type sausage. They reported that appearance, flavor, texture, nutritional value and other properties closely simulated that of bologna type sausages. It offered the advantages of not requiring ice or curing in frankfurter type products and even smoking was optional. Sanitation was believed

less of a problem and a wide range was available for product composition.

Glabe et al., (1956) studied the effects of Gelsoy as a binder for sausages and other food products. Gelsoy is a water-soluble, proteinaceous extract of defatted soybean meal which is characterized by the absence of the bitter or beany flavor. They reported that on an eight percent moisture basis the flakes contained 50 to 55 percent protein, 6.5 percent ash, and about 20 percent soluble carbohydrates. It was reported that under certain conditions Gelsoy is capable of holding ten times its weight in water, thus making it desirable as a binder in preventing fat and moisture separation. When used in combination with sodium hexametaphosphate and dextrine, three pounds of the Gelsoy combination was reported to have been as effective as six pounds of non-fat dry milk in its binding effect.

Hafner (1959) concluded that soybean proteins are, "by far the highest quality of any of the vegetable proteins, being about equal to milk and meat proteins." Gerrard (1955), in a discussion of sausages, reported that soya flour as a binder can be beneficial due to its unusually high protein content, its ability to absorb water comparable to other binders, as well as its contribution to improving the texture of the sausage. He also reported that a possible "anti-oxygenic" effect may be exerted by the flour.

Effectiveness of Non-fat Dry Milk Solids as a Sausage Binder.

Eckles et al., (1936), in discussing the development of dry milk by Grimwade, reported that on a commercial basis, dry milk was not manu-

factured until 1855. Dry milk was developed primarily as an infant food but soon spread into all areas of the food industry in which "normal" milk was used. They indicated that dry skim milk and a sweet-cream buttermilk had been used in certain sausage preparations for added food value and for their adhesive properties.

According to Cook and Day (1947), approximately 6.3 percent of the non-fat dry milk produced in 1941 was used in sausages. They reported that from eight to ten percent non-fat dry milk in the sausage formula gave good results. They also reported that improvements were observed in flavor, color, binding quality, and increased yield, since non-fat dry milk absorbs and retains from 1 to 1.7 times its own weight in moisture. In comparison with grain or vegetable flours, there was an increase in protein and mineral value.

Non-fat dry milk has been recommended for use, by the American Dry Milk Institute (1953), in bolognas, frankfurters, head cheese, beef loaf, pork sausage, and hamburger. They suggested that on the basis of food value, the vegetable or cereal binder most nearly approaching non-fat dry milk was that of soya flour. It was suggested that differences in cost were offset by the superior quality of animal protein in non-fat dry milk when compared with the proteins of soya flour. The average composition of non-fat dry milk as reported by the Institute is; 51 percent lactose, 37 percent protein, eight percent minerals, one percent fat, and three percent moisture. Significant amounts of natural riboflavin, thiamin, niacin, pantothenic acid, pyridoxin, and other water soluble vitamins are also reported to be present. They attributed improvements in color, texture, slicing

quality, flavor, and reduced shrinkage to the use of non-fat dry milk. Incorporation of eight percent non-fat dry milk, where federal or state laws do not conflict, was reported to increase nutritional value considerably.

Hunziker (1949) reported that non-fat dry milk was prepared from high quality sweet skimmed milk and normally contained about three percent moisture. The Federal Standards limit the moisture to five percent and fat content to 1.25 percent. The bulk of non-fat dry milk produced today is made by one of several spray drying methods. The heat treatment used is dependent upon the use for which the product is intended. Mrak and Stewart (1951) stated that with such products as cottage cheese, a minimum heat treatment was desired, whereas, with bread a high heat treatment was more desirable. They indicated that for such products as ice cream, pancake flour or sausages the type of heat treatment was less critical.

According to Swanson (1959), there are two major factors impeding wider usage of non-fat dry milk. First is the belief by public officials that inferior skim milk is used in producing non-fat dry milk and second that poor pasteurization of milk and/or drying temperatures, make conditions favorable for food poisoning organisms. Miller (1958) stated that non-fat dry milk was the principal milk product used in sausages and meat food products and that it was found as a common ingredient of cooked sausages.

As reported by Gerrard (1955), the addition of non-fat dry milk in sausage produces, "a richly flavored product, with an obvious increase in its food value." An experiment was conducted where rusk (a

type of dried bread preparation) was compared with cow's milk, reconstituted skimmed milk, and dried milk powder. Factors evaluated were keeping quality, color, flavor, and texture between control and treated sausages. The only variables were water and binder. Difficulty was experienced in evaluating flavor and texture, but he concluded that a sausage made with certain proportions of milk powder possessed a smooth creaminess which the others apparently lacked.

In the area of product development, Pahlke (1944) found non-fat dry milk was beneficial to sausage quality. Two new sausage type products were developed: Cheesefurters and Milkfurters. The cost and yield data were presented for frankfurters, cheesefurters, and milkfurters. He reported that 0.6 percent more moisture and 0.75 percent more protein were present in milkfurters after processing than in the control (frankfurters) when both types were stuffed in cellulose casing. Non-fat dry milk was added at a rate of eight pounds per 100 pounds of meat while the added moisture was 16 pounds. A processing loss of 13.91 percent was observed for the milkfurters as compared with 14.82 percent for the frankfurters where both were stuffed in cellulose casings. The cheesefurters under the same conditions lost only 11.7 percent.

Effectiveness of Phosphates as Sausage Binders. Miller (1958) reviewed briefly the application of phosphates in meats. Polyphosphates, a loosely used term to refer to various phosphates, have been accepted for use in certain foods such as cheese and some meats. According to Miller, the phosphates were believed to have a "hydration"

effect on proteins that was responsible for the increased water absorption that was characterized by swelling of the fibers and increased water retention. Their major purpose in meats was to decrease the amount of juice cooked out in cured meats during processing.

The M.I.D. regulations concerned with the application of phosphates in meats, stated that disodium, sodium hexameta-, sodium tripoly-, sodium pyro-, and sodium acid pyrophosphates may be used in chopped ham preparations in an amount not to exceed eight ounces per 100 pounds of the fresh uncured comminuted ham. Also, for primal cuts, up to five percent of such phosphates can be added to the curing pickle, provided that not more than 1/2 of one percent of added phosphate is present in the finished product.

While phosphates have not gained acceptance for sausages in this country, they have been used extensively for such purposes elsewhere, notably Germany. Morse (1955) conducted a commendable review of the German studies dealing with phosphates. He stated that two recognized fields of application exist: 1. cooked, whole meats, such as hams and picnics; 2. cooked, cured comminuted meats. He reported that phosphates acted by changing the pH and in turn increased water-holding capacity. They also possessed certain surface effects on fats that appeared to improve emulsification and at the same time minimize pocket formation in the product. They did not upgrade a poor meat product, according to Morse. He obtained up to five percent greater juice retention during processing.

Dopner (1949) reported, however, that the usual factors such as meat type, degree of chop, and handling procedure played a far more

important role in moisture loss than did addition of phosphate. He concluded that boiled phosphate-treated hams showed less shrink than controls due to greater juice retention during boiling.

Bendall (1954) studied the effects of orthophosphate, pyrophosphate, "calgon," and phosphate glass. All were reported to have increased the "uncooked volume" of minced rabbit muscle by ten to 20 percent when used at a concentration of 0.5 percent in a solution containing equal amounts of meat and water. On cooking, only 65 to 75 percent of the volume of the fresh meat was retained. He concluded that of the phosphates tested, only pyrophosphate had a specific swelling effect on lean meat and that this effect was enhanced with increasing ionic strength. Swift and Ellis (1956), however, were not able to observe the specific swelling effect for pyrophosphate but concluded that effectiveness was related to ionic strength and pH of the solution applied. They also reported that pyrophosphates dissolved proteins, especially (acto) myosin, and the extent was affected by pH and ionic strength. Other factors having an influence on the effectiveness of phosphates in meat were temperature and time and specific effects were caused by ions such as I^- and Mg^{++} . According to Wilson (1954), the addition of disodium, sodium hexameta-, sodium tripoly-, and sodium pyrophosphate failed to show measurable benefits in moisture retention, texture, color fixation, or rate of fading when studied in comminuted products, such as bologna.

Tarladgis (1959), in studying the effect of sodium tripolyphosphate on irradiated and unirradiated cooked pork, noted decreased drip losses where phosphate was employed. This, he concluded, was due to

increased pH of the meat and possibly complexing of polyvalent cations. Brissey (1952), in a patent, suggested that orthophosphates can be useful in reducing loss of juice during cooking. He attributed this effect to the high pH. Tims and Watts (1958) studied the effects of sodium-tripoly-, -hexameta-, and -pyrophosphates on juice loss and oxidative changes in pork. They concluded that phosphates generally exerted an effect on juice retention where samples were of similar pH values.

Fermented Sausages. The practice of permitting fermentation processes to proceed in the manufacture of certain sausages has been well established. Niven (1957) related that, in general, sausage manufacturers depended upon chance contamination of desirable type microorganisms for successful production of such sausages as thuringer, Lebanon bologna, cervelat, Genoa salami, or summer sausage. The development of the desired tangy flavor was due to lactic acid fermentation of the sugar present in the sausage. He reported that with fermented sausages, it is essential that the bacteria have a chance to grow during processing if the desired flavor is to be acquired. This requires long holding periods where chance contamination is depended upon. With this type of inoculation, the sausage maker encounters a rather high incidence of failures in many cases due to the predominance of spoilage microorganisms rather than those of a desirable type.

The same authors stated that with the addition of a pure starter culture (Pediococcus cerevisiae), spoilage such as gassiness, softening, discoloration, nitrite burn, and mere lack of flavor should be avoided. They suggested that a suitable summer sausage could be produced

within 48 hours after grinding. The American Meat Institute Foundation (1956) stated that the process time required for producing a satisfactory summer sausage could be reduced from 144 3/4 hours to 48 1/2 hours by elimination of the holding, mixing, and tempering periods where Pediococcus cerevisiae was employed. This culture is commercially available in a dry form and it was recommended that one ounce of the dried preparation be dissolved in three ounces of water. This quantity was reported as sufficient for inoculating 100 pounds of meat, and should be added during mixing following the addition of cure and spices. The use of bacterial starters of the acidophilus type have been approved by the M.I.D. for sausages such as thuringer, Lebanon bologna, cerevelat, salami, and pork roll at the rate of 0.5 percent.

Deibel and Evans (1957) reported that while nitrite is an essential ingredient in cured meat products, if an excess is added or produced, the product may develop "nitrite burn", giving a greenish or grey color due to pigment oxidation. The amount of nitrite required to cause this condition is dependent upon the degree of acidity (pH) of the product. As the acidity is increased, smaller amounts of nitrite are required to cause this discoloration. For fermented sausages, they recommended that a mixed cure be used that provides 1/8 ounce of nitrite and 1/8 ounce of nitrate per 100 pounds of meat. This would provide a maximum of 140 p.p.m. of nitrite in the sausage, which is well below M.I.D. regulations of 200 p.p.m. residual nitrite.

EXPERIMENTAL PROCEDURE

Comparison studies. Preliminary studies were conducted to establish the most suitable processing procedures such as, chopping time, stuffing techniques, smoking time and temperature, and chilling and storage conditions. Individual treatments were prepared in 25 pound quantities as determined by the capacity of the silent-cutter employed.

Since the use of non-fat dry milk makes it possible to add more moisture, it was necessary to establish the rate at which moisture (as ice) should be increased as the non-fat dry milk was increased from zero to 20 percent of the finished product. According to M.I.D. regulations for cooked sausages, moisture in the finished product cannot exceed four times the protein content plus ten. Since non-fat dry milk contains approximately 37 percent protein, it enables the sausage manufacturer to incorporate into the product, moisture in excess of that permitted if non-fat dry milk was not employed. State regulations may deviate from this as does the Michigan Comminuted Meat Law (1954, sec. 2,a) which states that for Grade I sausage, "The total percentage of moisture in the finished product shall not exceed 65%. The total percentage of protein shall not be less than 12%."

In addition to preliminary trials, four comparison studies were conducted with each being replicated as nearly as possible within two to four weeks. The first comparison, Table I, included five batches per replication and was conducted to determine the effects of non-fat dry milk on the various quality and processing characteristics of bologna. The formulations for this comparison are given in Appendix A, Table 1.

Table 1. Comparison of various levels of NFDM¹ in bologna

Percent non-fat dry milk				
0 ²	3.5	10	15	20
¹ Non-fat dry milk				
² Control				

The second comparison (Table 2) included 12 batches of bologna for each replication. Three levels of non-fat dry milk were studied in this comparison in which four types of meat were employed with each level of non-fat dry milk. The beef and pork used in the formulation of this comparison were added in equal amounts. The binding quality of the formulations was varied by substitution of fat or pork hearts for the regular pork trim normally utilized. The pork contained 40, 50, and 90 percent lean for high fat, regular binding, and low fat, respectively. The low binding formulation contained pork hearts, substituted for half of the pork, and the remainder of the pork was regular binding. The formulations for this comparison are given in Appendix A, Table 2.

Table II. Comparison of three levels of NFDM in bologna containing meat of four binding qualities

Percent non-fat dry milk		
0	3.5	10
regular binding ¹	regular binding	regular binding
low fat	low fat	low fat
high fat	high fat	high fat
low binding	low binding	low binding
¹ Control batch		

The binders studied in the third comparison included soya grits, non-fat dry milk, and phosphates (a mixture containing 25 percent cross-linked potassium Kurrol's salt $(KPO_3)_n$ and 75 percent tetra sodium pyrophosphate $(Na_4P_2O_7)$). The phosphate mixture was added at the rate of 4.7 ounces per 100 pounds of meat. Sixteen batches were prepared (Table III) for each replication and included the different types of meat used in the second comparison. The formulations for the third comparison are presented in Appendix A, Table 3.

Table III. Comparison of different binders in bologna containing meat of four binding qualities

Control	10% NFDM	10% Soya Grits	Phosphate (4.7 oz./100 lbs. meat)
Regular binding ¹	regular binding	regular binding	regular binding
low fat	low fat	low fat	low fat
high fat	high fat	high fat	high fat
low binding	low binding	low binding	low binding

¹Control batch

The fourth comparison (Table IV) consisted of eight batches per replication. There were four batches of bologna and four of thuringer. For bologna, the variables were one level of non-fat dry milk, with and without sodium tripolyphosphate $(Na_5P_3O_{10})$ and two levels of fermented non-fat dry milk with and without sodium tripolyphosphate.

With thuringer, however, the milk binder was at the same level in all batches. A starter culture, Pediococcus cerevisiae, was added (1 oz./100 lb. of meat) to batches of thuringer receiving non-fat dry milk in order to obtain comparative results on the degree of tanginess

developed with culture to that in batches where fermented non-fat dry milk was employed without added culture. For each type of non-fat dry milk, one batch contained sodium tripolyphosphate at the rate of six ounces per 100 pounds of meat.

Preliminary studies had revealed that where fermented non-fat dry milk was used, there was an increase in the amount of separation on cooking and a resultant poorer texture. The phosphate was added in an effort to overcome these effects. Formulations for this comparison will be found in Appendix A, Table 4.

Table IV. Comparison of NFDM and FNFDM¹ in bologna and thuringer

	Percent NFDM		Percent FNFDM	
Bologna	3.5	3.5 + P ²	3.5 + P	7.5 + P
Thuringer	3.5 + C ³	3.5 + P + C	3.5	3.5 + P

¹Fermented non-fat dry milk

²Sodium tripolyphosphate (6 oz./100 lb. meat)

³Starter culture added (Pediococcus cerevisiae)

Selection of ingredients. Lean beef was obtained from either utility cows or from bull carcasses. In all instances, the replications for any given experiment contained one or the other. Pork trim used in this study was approximately 65 percent lean except for the second and third comparison studies in which 40, 50, and 90 percent lean trim was employed. Pork hearts were also used in the second and third comparisons.

All meat was frozen and stored in a -20°F. plate freezer prior to being used, in order to reduce variation between replications.

Where entire sides or carcasses were boned out, the meat was ground through a 1/2 inch plate, mixed, and vacuum packaged in Cryovac bags prior to freezing. This was to insure, as nearly as possible, similar composition for replications within any given comparison study.

The curing ingredients selected included salt, sugar, sodium nitrate, sodium nitrite, and sodium ascorbate. The exact amounts of each are given in Appendix A, Tables 1-4. The spices used in this study included extractives of pepper, nutmeg, ginger, coriander, all-spice on a salt carrier, and garlic powder and were prepared by a commercial firm according to the formulation presented in Appendix A, Table 5.

A starter culture of Pediococcus cerevisiae was employed at the rate of one ounce per 100 pounds of meat in the fourth comparison study. The culture was obtained through the courtesy of a Michigan sausage producer and was stored at 38°F. until ready for use. The culture was prepared by mixing with 20 ml. of water 15 to 30 minutes prior to adding it to the emulsion.

Flaked ice was used in the preparation of bologna. Non-fat dry milk was high temperature spray processed and obtained from the Michigan State University Food Science Department.

Preparation of emulsions. The meat was permitted to thaw at room temperature for four to six hours prior to grinding. The beef and pork were ground separately through a 1/2 inch plate. The beef was then reground through a 1/8 inch plate and the pork through a 3/16 inch plate. Grinding was carried out approximately 12 hours prior to chopping and the meat was then stored at 38°F. until used.

The chopping procedure used in making bologna was to add the beef, cure, seasoning ingredients, and half of the ice. Chopping was conducted for four minutes before adding the remainder of the ice and binder, if it was to be added. The chop was continued 1 1/2 minutes before adding the pork, after which chopping was continued for four minutes, or until the emulsion reached a temperature of 56°F.

In preparing thuringer, mixing was accomplished by adding first the beef, cure, seasoning, and half of the water. After mixing two minutes, the pork was added and mixed for an additional two minutes. Then the binder, remainder of the water, and culture were added and mixing was continued for three minutes and the product was then ready for stuffing. The machine used in the mixing operation was comparable to that found in a small commercial operation.

Stuffing procedure. The stuffing operation employed an air-driven stuffer similar to those used in small commercial operations. The emulsions of each batch were stuffed into three (5 x 35) fibrous casings. The stalks of bologna were labeled one, two, and three according to their order of stuffing and hung on a smokehouse tree in random order except that the second stalk from each batch was hung on the lower level. Stalk one was used for shrink and yield determinations, whereas the second stalk was used for moisture, protein, fat and pH determinations, color evaluation and tensile strength measurements as well as for following the internal temperature during cooking. The third stalk was used for taste panel evaluation. All stalks were weighed individually on a gram balance, rinsed with warm water and placed in the smokehouse.

Cooking and Smoking Procedure. An airconditioned smokehouse was used in this study. For cooking and smoking bologna, the smokehouse was preheated to 175°F. and the bologna was cooked at this temperature for 35 minutes. The temperature was reduced to 165°F. for the remainder of the heat process. Smoking was started after the first 35 minutes, and continued until an internal temperature of 152°F. had been reached by all bolognas. This usually required a total time in the smokehouse of from four to five hours.

Thuringer was allowed to remain at room temperature (approximately 70°F.) for about five hours after stuffing. It was then placed in the smokehouse that was preheated to 90°F. Drying at this temperature continued for 18 hours without smoke to permit the cultured batches to develop the desired tangy flavor. The temperature was then increased to 100°F. for 24 hours in the presence of smoke. Following this 24 hour period, temperature was increased 20°F. each 30 minutes until a smokehouse temperature of 160°F. had been attained. The thuringer was cooked, without smoke, until an internal temperature of 152°F. was reached.

Showering and chilling. According to Tauber (1957), showering is one of the most critical operations in sausage making. He suggested that it serves the purpose of reducing the temperature of the sausage, prevents or reduces the incidence of casing breakage, enhances "peelability" of the casing from the sausage and reduces shriveling of the product upon storage. He stated that, in addition, excessive showering leaches the salt from the surface of the sausage, thus reducing any bacteriostatic properties that would have been afforded by the presence

of salt. Other problems reportedly due to poorly controlled showering, are streaking of the surface by misdirected showers, and permitting excessive absorption of water by sausage. He suggested that sausages be showered to an internal temperature of 90 to 100°F.

In this study the procedure employed was to rinse the sausages with hot water (approximately 140°F.) following smoking, to remove surface fat from the casings. The bologna was then showered with a cold water spray until an internal temperature of 90°F. was reached, which normally required about one hour. The thuringer was permitted to hang at room temperature for 1 1/2 hours without showering before being placed in the cooler. Both bologna and thuringer were stored in a 38°F. cooler until the various tests of quality could be completed.

Yield and shrinkage. The sausages were weighed on a gram balance as individual stalks before smoking and after chilling (before going to the 38°F. cooler) for calculating the yield, which is reported as an average of the percent yield for the three stalks of each batch.

For shrinkage determinations, the weight of stalk number one of each batch was taken after a seven day storage period. The method used to compute the seven day shrink was based on the difference in weight after smoke and weight at the end of seven days storage at 38°F.

Chemical analyses. Samples were taken from the second stalk of each batch. One inch slices were removed 1 1/2 inch from each end and from the center. The three slices were then ground through a 5/64 inch plate of a sample grinder four times, mixed thoroughly, and a small portion was sealed in a sample jar and frozen at -20°F. for later analyses.

Approximately five gram samples were taken in duplicate for combined moisture and fat determinations. The samples were weighed into disposable aluminum cups and dried 24 hours at 100°C. in a hot-air oven. The moisture in the samples was determined on a wet weight basis which was the difference in weight between the wet and dried sample divided by the weight of the wet sample. After completing the moisture determination, the dried samples were extracted with anhydrous ether for four hours using a Goldfish Fat Extractor. The percent fat was computed on a wet weight basis. A summary of values obtained for moisture and fat are recorded in Appendix B.

Protein determinations were conducted by the Kjeldahl-Gunning method as outlined in A.O.A.C. (1955). A factor of 6.25 was used in converting percent nitrogen to protein. It should be noted that for milk, a factor of 6.38 is more frequently used, therefore, a slight error is present in the results as presented in this study, due to the presence of various amounts of non-fat dry milk in the sausage being tested. This is not believed to be significant, however.

Method for measuring pH. After grinding the sample for chemical analyses, the ground sample remaining was used for determination of pH with a Beckman Model G pH Meter. The electrodes were placed directly in the ground samples and the observed readings were recorded.

Method for measuring color. Munsell (1916) described an objective method for the measurement of color through the use of combinations of spinning colored disks. He divided color into three basic dimensions: Hue, Value, and Chroma which included the actual color, the

lightness or darkness of the color, and the concentration or amount of color, respectively. Each disk has a particular renotation value or nominal value. In this study the disks used and their renotation values were as follows: N 4/; 10 R 7/8; 7.5 YR 5/6; N 8/. The sequence for presenting renotation values is Hue, Value, and Chroma. Due to the influence of both light and temperature on the rate of color change, it was necessary that the evaluation be conducted in a 38°F. cooler to reduce this change.

Munsell spinning disks were used for evaluating the color observed on the surface of bologna and thuringer slices. The method of sampling was as follows: after removing the one inch slice from the center of stalk two for chemical analyses, an adjacent slice (approximately 3/4 inch) was removed for color evaluation. The color was always observed on the side of the slice most distant from the center to reduce variation attributable to dessication. After gaining a working knowledge of the method with preliminary studies, a time interval of four minutes was selected as most suitable. This time interval was measured from the cutting of the sample on a standard meat slicer, until the color disks were satisfactorily matched with the color of the sample. Renotation values were computed for Hue, Value, and Chroma according to the procedures described by Voegeli (1952) and Saffle (1958).

The sample taken as a standard for computing the Index of Fading described by Nickerson (1946), was from bologna containing 3.5 percent non-fat dry milk. Five consecutive slices from the same stalk were

evaluated for color using the Munsell spinning disks when establishing a standard for calculating the Index of Fading. Renotation values were obtained for each slice and an arithmetic average calculated which was the standardized value used. This procedure was used by Henry (1959) in a study concerned with color in pork muscles.

Tensile strength measurement. The instrument used for measuring tensile strength was that described by Swift and Ellis (1957) except for minor changes. Essentially, the described apparatus was constructed of wood and included two small blocks upon which a strip of bologna was placed. One wooden arm above each block was mounted so that it could be moved into position to hold one end of the bologna strip. A long wooden dowl having a disk mounted on one end and a small wooden block, capable of going between the two previously mentioned wooden blocks, on the opposite (bottom) end was used to exert force upon the strip of bologna. A beaker resting upon the disk was filled with sand at a constant rate until the strip of bologna broke under the pressure. The beaker and sand were then weighed on a gram balance and this value recorded.

The changes instituted for this study included rounding the surfaces of all blocks coming in contact with the meat in an effort to reduce the shearing action; water, rather than sand, was added to the beaker by siphoning from a large container; dual blocks were used in supporting the strips of bologna and a two-kilogram weight replaced each arm for holding the bologna strip.

The method of sampling in this study was to remove ten consecutive slices, 4 x 22.2 millimeters. The length of the slices was equal to the diameter of the sausage. These slices were removed from the second stalk of each batch adjacent to, but following the removal of the sample for color evaluation as described previously.

Taste panel methods. To evaluate such factors as flavor, juiciness, texture, and tenderness, taste panels were used. Since it is quite difficult to distinguish either texture or tenderness without being unduly influenced by the other, it was decided to combine the two terms and only three taste evaluations were conducted for each sample. They were: flavor preference, juiciness difference, and texture-tenderness difference tests.

The panel was of a consumer type rather than a trained group and was made up almost entirely of Michigan State University personnel from several departments. Principally, however, the staff of the Meats Laboratory was utilized. Flavor preference was determined by using a hedonic scale, Fig. 1. The panel members were instructed to indicate the term for each sample that most nearly represented their degree of like or dislike from the standpoint of flavor preference and not to compare the different samples. Fifteen panel members were used for all evaluations conducted in this study and not more than six samples were presented at one time.

Differences in juiciness were determined using the form given in Fig. 2. The panel members were instructed to compare the unknown samples with a standard and indicate the degree of difference in juiciness, if any difference existed. If such difference did exist, they were

MICHIGAN STATE UNIVERSITY - Meats Laboratory

Flavor Preference Test

Name _____		Plate No. _____		Date _____	
Code _____		Code _____		Code _____	
Code _____		Code _____		Code _____	
<u> </u> Like Extremely	<u> </u> Like Extremely	<u> </u> Like Extremely	<u> </u> Like Extremely	<u> </u> Like Extremely	<u> </u> Like Extremely
<u> </u> Like Very much	<u> </u> Like Very much	<u> </u> Like Very much	<u> </u> Like Very much	<u> </u> Like Very much	<u> </u> Like Very much
<u> </u> Like Moderately	<u> </u> Like Moderately	<u> </u> Like Moderately	<u> </u> Like Moderately	<u> </u> Like Moderately	<u> </u> Like Moderately
<u> </u> Like Slightly	<u> </u> Like Slightly	<u> </u> Like Slightly	<u> </u> Like Slightly	<u> </u> Like Slightly	<u> </u> Like Slightly
<u> </u> Neither like Nor dislike	<u> </u> Neither like Nor dislike	<u> </u> Neither like Nor dislike	<u> </u> Neither like Nor dislike	<u> </u> Neither like Nor dislike	<u> </u> Neither like Nor dislike
<u> </u> Dislike Slightly	<u> </u> Dislike Slightly	<u> </u> Dislike Slightly	<u> </u> Dislike Slightly	<u> </u> Dislike Slightly	<u> </u> Dislike Slightly
<u> </u> Dislike Moderately	<u> </u> Dislike Moderately	<u> </u> Dislike Moderately	<u> </u> Dislike Moderately	<u> </u> Dislike Moderately	<u> </u> Dislike Moderately
<u> </u> Dislike Very much	<u> </u> Dislike Very much	<u> </u> Dislike Very much	<u> </u> Dislike Very much	<u> </u> Dislike Very much	<u> </u> Dislike Very much
<u> </u> Dislike Extremely	<u> </u> Dislike Extremely	<u> </u> Dislike Extremely	<u> </u> Dislike Extremely	<u> </u> Dislike Extremely	<u> </u> Dislike Extremely
Comments:	Comments:	Comments:	Comments:	Comments:	Comments:

Fig. 1. Flavor Preference Score Sheet

Score Sheet Juiciness Difference Evaluation

Name _____
Date _____

Plate No. _____

Instructions

1. Enter at the head of each column the code number of each sample in the test.
2. Determine by juiciness comparisons with the reference sample the degree of juiciness difference for each numbered sample.
 - a. If you do not detect any juiciness difference, place a check in the box opposite the word None.
 - b. If in your judgment any juiciness difference exists, place a check in one of the other eight boxes opposite or between the terms which best describes the degree of juiciness difference.
3. After rating the juiciness difference, place a check in one of the two boxes at the bottom of the column indicating whether the juiciness of the numbered sample is more juicy or less juicy to you.

Note: The reference sample should be re-tasted as often as necessary to determine the degree of juiciness difference for each sample.

	Sample Number					
Degree of juiciness difference	_____	_____	_____	_____	_____	_____
None	()	()	()	()	()	()
.	()	()	()	()	()	()
Slight	()	()	()	()	()	()
.	()	()	()	()	()	()
Moderate	()	()	()	()	()	()
.	()	()	()	()	()	()
Large	()	()	()	()	()	()
.	()	()	()	()	()	()
Extreme	()	()	()	()	()	()
.	()	()	()	()	()	()
More juicy	_____	_____	_____	_____	_____	_____
Less juicy	_____	_____	_____	_____	_____	_____

Fig. 2. Juiciness Panel Score Sheet

to indicate if the unknown was more or less juicy than the standard. The standard for the first and second comparisons was not always the same due, in part, to the large amount of bologna required for reference. A single standard was used in the third comparison and one standard was used for each type of meat in the fourth comparison.

Texture-Tenderness differences were determined according to the form presented in Fig. 3. Essentially, the procedure was the same as for juiciness with only the terms to be evaluated being changed. The samples were prepared by removing 3.5 to four millimeter slices from stalk three of each batch and cutting the slices into fourths, each fourth representing one sample. The panel members were given one sample of standard for each unknown; however, additional standard samples were available upon request. The samples for taste panel evaluation were removed from the third stalk of each batch by starting approximately three inches from the closed end as determined during the stuffing operation. Removal of slices progressed toward the other end as more samples were required. When removing samples for subsequent panel tests, the first three or four slices were discarded because of surface dessication.

Statistical analyses. For purposes of ascertaining whether or not differences in juiciness and texture-tenderness were significant, one and two factor range tests were employed, Tukey (1953). For analyzing all other data, an analysis of variance was computed as outlined by Snedecor (1956). Where significant differences existed, a multiple range and multiple F test (Duncan 1955) was used to determine the significance between means.

Score Sheet Texture-Tenderness Difference Evaluation

Name _____

Plate No. _____

Date _____

Instructions

1. Enter at the head of each column the code number of each sample in the test.

2. Determine by texture-tenderness comparisons with the reference sample the degree of texture-tenderness difference for each numbered sample.

a. If you do not detect any texture-tenderness difference, place a check in the box opposite the word None.

b. If in your judgment any texture-tenderness difference exists, place a check in one of the other eight boxes opposite or between the terms which best describes the degree of texture-tenderness difference.

3. After rating the texture-tenderness difference, place a check in one of the two boxes at the bottom of the column indicating whether the texture-tenderness of the numbered sample is more tender or less tender to you.

Note: The reference sample should be re-tasted as often as necessary to determine the degree of texture-tenderness difference for each sample.

	Sample Number					
Degree of texture-tenderness difference	_____	_____	_____	_____	_____	_____
None	()	()	()	()	()	()
.	()	()	()	()	()	()
Slight	()	()	()	()	()	()
.	()	()	()	()	()	()
Moderate	()	()	()	()	()	()
.	()	()	()	()	()	()
Large	()	()	()	()	()	()
.	()	()	()	()	()	()
Extreme	()	()	()	()	()	()

More tender	_____	_____	_____	_____	_____	_____
Less tender	_____	_____	_____	_____	_____	_____

Fig. 3. Texture-Tenderness Panel Score Sheet

RESULTS AND DISCUSSION

Preliminary studies. In order to become familiar with sausage equipment, several preliminary studies were made. It was necessary to establish certain of the processing procedures to prevent fat-capping and formation of jelly pockets. Results from the preliminary studies indicated that a chopping time of 9.5 minutes, or a maximum emulsion temperature of 56°F., produced satisfactory bologna, if other factors such as rate of heating, maximum cooking temperature, and total cooking time were controlled. Using an initial smokehouse temperature of 175°F. for 35 minutes and then reducing this to 165°F. for the remainder of the heat process proved very desirable in preventing fat separation in most cases.

Another problem solved by preliminary studies was the rate at which added ice had to be increased as the percent non-fat dry milk was increased. Even though non-fat dry milk absorbs from one to 1.7 times its own weight of water (American Dry Milk Institute, 1953), it was found that additional ice on a pound per pound basis when non-fat dry milk was used, produced bologna with the desired non-fat dry milk content.

In presenting the results, the factors evaluated will be discussed on the basis of either an analysis of variance (Snedecor 1956) or a difference by range test (Tukey 1953). The error term for the analysis of variance varied, depending upon the factor being evaluated. Where significance was established when testing interactions with the first order error term, a new error term was used to test the various treatments for significant differences and the specific error term employed

in these instances will be explained as encountered. Where significance was not established when testing interactions, the first order error term was used for testing treatments for significant differences. Where the analysis of variance showed significant differences between treatments, a studentized range test (Duncan 1955) was employed to locate the treatments that were significantly different. In the first and fourth comparisons, a one-factor range test was employed for analyzing juiciness and texture-tenderness differences while a two-factor range test was used in analyzing these factors in the second and third comparisons.

The mean values for all factors evaluated are given for comparison one through four in Appendix B, Tables 1-4, respectively.

Investigation of the effects of non-fat dry milk on processing and quality characteristics of bologna, Comparison I. This comparison was designed to test the effects of various levels of non-fat dry milk upon processing and quality characteristics of bologna.

Percent yield. The results of the analysis of variance of percent yield, presented in Table V, show significance for both treatments and replications. The interaction of treatment x replication did not approach significance. Since there were only two replications, it was concluded without going through further analysis that the variation between replications was probably due to uncontrollable variations in the processing techniques.

Table V. Analysis of variance of percent yield of bologna from comparison I

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	4	13.85	3.46	8.24**
Replication	1	67.59	67.59	160.93**
Tr. x rep.	4	1.31	0.33	<1.0
Error	20	8.45	0.42	
Total	29	91.20		

**Significant at 1% level

Table VI shows the mean values for each trial, obtained by averaging the percent yield of the three stalks per batch. It is readily apparent from the tabled values that the same relationship existed within replications except for the 15 percent treatment of trial 2. It can be observed that all batches of trial 2 had a greater percent yield than its counter part in trial 1 and explains the significance between replications. On studying the processing records, it was observed that in trial 1, difficulty was encountered in holding the smokehouse temperature at 175°F. during the first 35 minutes of the heat process and as a result of this, the total process time was approximately five hours for the first trial as compared with about four hours for the second trial. With the longer heat process it was expected, as later results revealed (see Appendix B, Table 1), that the percent yield and shrinkage, moisture and protein content, and pH values were lower than with a shorter process time. The percent fat was increased with the longer heating time. These changes were due to the increased loss of moisture with extended heating even though the same internal temperature was attained in both trials. In addition, the bologna processed for a longer time would be expected to be tougher and less juicy. This has been pointed out in a report by Swift et al. (1954) in which it was stated that both moisture and fat content affected the tenderness and juiciness of bologna. They noted, however, that these factors were influenced more by changes in moisture than fat.

The results of the studentized range test are given in Table VI. It can be observed from these results that the 3.5 percent non-fat dry milk treatment had a greater percent yield than either the control or

1. The first part of the document discusses the importance of maintaining accurate records of all transactions and activities. It emphasizes that this is essential for ensuring transparency and accountability in the organization's operations.

2. The second part of the document outlines the various methods and techniques used to collect and analyze data. It includes a detailed description of the sampling process and the statistical tools employed to interpret the results.

3. The third part of the document presents the findings of the study. It provides a comprehensive overview of the data collected and the conclusions drawn from the analysis. The findings are presented in a clear and concise manner, allowing for easy interpretation and understanding.

4. The fourth part of the document discusses the implications of the findings and the potential for future research. It highlights the areas where further investigation is needed and suggests ways in which the results can be applied to improve organizational performance.

5. The fifth part of the document provides a summary of the key points discussed throughout the document. It reiterates the importance of accurate record-keeping and the need for ongoing research and improvement.

20 percent non-fat dry milk treatments. These differences were at the one percent level of significance. The control batch had the lowest yield of all batches tested. Where non-fat dry milk was included in the formulation, there was a definite trend toward increased yield as the percent non-fat dry milk was decreased.

Table VI. Percent yield of bologna from comparison I as influenced by treatment.

Treatment % NFDM	Mean (3 stalks/trial)		Means ranked (6 stalk av.)	$\bar{X}$ -90.98	$\bar{X}$ -91.15	$\bar{X}$ -92.01	$\bar{X}$ -92.16
	Trial 1	Trial 2					
3.5	91.23	94.42	92.82	1.84**	1.67**	0.81	0.66
10.0	90.77	93.54	92.16	1.18	1.01	0.15	
15.0	90.35	93.68	92.01	1.03	0.86		
20.0	89.44	92.86	91.15	0.17			
Control	89.83	92.13	90.98				

**Significant at 1% level

Heat treatment. The results obtained from following the rate of heating revealed only slight differences between treatments. The addition of up to 20 percent non-fat dry milk did not have a consistent influence upon heating rate although larger quantities of added moisture were present with the higher levels of non-fat dry milk and it was expected that this in itself would yield observable differences in the rate of heat transfer. The largest differences between treatments were observed after the first thirty minutes in the smokehouse. Product temperatures varied from four to 12°F. As the heat treatment was continued, these differences were reduced to approximately four degrees at the end of 90 minutes.

Percent shrinkage. In conducting an analysis of variance of the shrink data, it was observed that significant differences between treat-

ments or replications did not exist. This is clearly shown in Table VII. These results are not in agreement with those reported by The American Dry Milk Institute (1953) that stated that addition of non-fat dry milk decreased shrinkage. This difference could have been due to differences in storage time or conditions, such as temperature or relative humidity. It might be well to point out that percent shrinkage is directly related to the moisture content of the finished product. The greater the moisture content, the greater will be the shrinkage. This will become more evident in the discussion which follows.

Table VII. Analysis of variance of percent shrink (7 da.) of bologna from comparison I

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	4	3.54	0.88	2.84
Replication	1	0.95	0.95	3.06
Tr. x rep.	4	1.25	0.31	
Total	9	5.74		

Percent moisture. As may be seen from the analysis in Table VIII, the treatments did not differ significantly in percent moisture; however, replications were highly significant. This difference serves to point out the difficulty encountered in producing sausage of uniform quality and composition. As mentioned earlier, sufficient meat was obtained at one time for both trials of any particular comparison so as to minimize the variation in meat composition. As indicated by Maroney and Landmann (1959), meats used in sausage preparations showed considerable variation in moisture, protein, and fat content even when taken from "identical lots". Pahlke (1944) was able to show increased moisture and protein

in frankfurters and cheese furters through the use of added non-fat dry milk. The mean values for percent moisture are presented in Table IX. A part of this variation may be attributable to sampling technique although, for the most part, this was not suspected. The major variation between replications was believed due to the differences in total process time as previously discussed.

Table VIII. Analysis of variance of percent moisture in bologna from comparison I

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	4	0.70	0.18	6.00
Replication	1	8.61	8.61	287.00**
Tr. x rep.	4	0.12	0.03	
Total	9	9.43		

**Significant at 1% level

Percent protein. Presented in Table X are the results of an analysis of variance of percent protein. It can be observed that differences in treatments and replication were not significant. Increasing non-fat dry milk in the formulation of bologna up to 20 percent did not significantly increase the percent protein in the finished product, however, the mean values (Appendix B, Table 1) show a trend toward increased protein with increased non-fat dry milk. The variation observed within treatments prevented this trend from showing significance.

In addition, these results could be interpreted as revealing that with added moisture, which was increased from 20 to 39.2 pounds per 100 pounds of sausage as the non-fat dry milk was increased to 20 percent, there was no significant decrease in the protein content of the finished product.

Table IX. Mean values of percent moisture of bologna from comparison I

Trial	Percent NFDM				
	Control	3.5	10	15	20
1	53.72	56.46	56.31	56.03	56.87
2	60.68	61.57	61.70	62.41	62.38

Table X. Analysis of variance of percent protein of bologna from comparison I

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	4	1.55	0.39	4.33
Replication	1	0.68	0.68	7.56
Tr. x rep.	4	0.35	0.09	
Total	9	2.58		

Percent fat. Table XI shows the results of the analysis of variance of the percent fat. Significant differences were observed between treatments and replications.

The differences observed between replications were presumed to be due to variations in the fat content of the raw ingredients and/or variations in total process time. The average percent fat for each treatment according to trials is presented in Table XII. With increased non-fat dry milk, the amount of pork trim in the formulation was reduced and one would expect a decreased fat content as was revealed from the results shown in Table XII. With the mean values ranked in descending order of magnitude, it can be observed that any two adjacent treatments differ significantly at the five percent level. Differences in percent fat at the one percent level of significance can be observed between any two treatments separated by an intermediate treatment on the basis of mean values.

Table XI. Analysis of variance of percent fat in bologna from comparison I

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	4	250.45	62.61	93.45**
Replication	1	90.78	90.78	135.49**
Tr. x rep.	4	2.68	0.67	
Total	9	343.91		

**Significant at 1% level

pH determinations. The results presented in Table XIII show that bologna containing non-fat dry milk had higher pH values than control batches. The presence, rather than the amount, of non-fat dry milk employed appeared to be the important factor at the levels tested. The variation between trials was attributed to differences in final composition as influenced by variation in total process time.

Table XII. Percent fat in bologna from comparison I as influenced by treatment

Treatment	Trial	Trial	Mean of				
% NFDM	1	2	trials	$\bar{X}$ -12.62	$\bar{X}$ -16.07	$\bar{X}$ -20.04	$\bar{X}$ -23.30
			ranked				
Control	30.53	22.86	26.70	14.08**	10.63**	6.66**	3.40*
3.5	25.84	20.76	23.30	10.68**	7.23**	3.26*	
10.0	22.64	17.43	20.04	7.42**	3.97*		
15.0	19.48	12.66	16.07	3.45*			
20.0	15.30	9.95	12.62				

*Significant at 5% level

**Significant at 1% level

With the longer process time used for trial 1 there was a greater loss of moisture. This change in moisture content affected the concentration of other ingredients such as protein and fat and as a result the pH values became lower with the extended heat treatment. Wierbicki et al. (1956) stated that shrink on cooking was based on the water-

1. The first part of the report is a general introduction to the subject of the study. It discusses the importance of the study and the objectives of the research.

2. The second part of the report is a detailed description of the methodology used in the study. It includes information about the sample size, the data collection methods, and the statistical analysis techniques.

3. The third part of the report is a discussion of the results of the study. It presents the findings of the research and discusses their implications for the field of study.

holding capacity of meat proteins. Their results showed that as pH shifted away from the isoelectric point or became more alkaline, the water-holding capacity was increased. This would support the results found in this comparison since lower pH values were obtained in batches showing the greatest cooking losses.

Color evaluation. The results of the Color Renotation and Index of Fading values, Table XIII, showed that with increased levels of non-fat dry milk the color of the bologna went from reddish, to yellow-red. The appearance was that of a lighter colored product. This was expected since a large portion of meat, and thus total meat pigment (myoglobin), was replaced with non-fat dry milk. At the 20 percent level, the total meat per batch was 10.2 pounds as compared with 20 pounds for the control batch. The positive sign associated with the index of fading indicated that the samples were lighter than the standard.

Table XIII. pH, color renotation, and index of fading values of bologna from comparison I

Treatment % NFDM	pH values		Renotation values				Index of fading ^a	
	Trial	Trial	Trial 1		Trial 2		Trial 1	Trial 2
	1	2						
Control	6.1	6.2	1.3YR	6.3/2.7	1.0YR	6.3/3.4	+3.9	+2.9
3.5	6.2	6.3	1.6YR	6.3/2.8	2.3YR	6.3/3.0	+3.6	+3.8
10.0	6.2	6.3	3.7YR	6.3/2.6	2.7YR	6.3/3.2	+6.5	+4.0
15.0	6.2	6.3	2.7YR	6.3/3.1	3.1YR	6.3/3.0	+4.3	+4.9
20.0	6.2	6.4	3.6YR	6.3/2.8	3.7YR	6.3/2.7	+5.5	+6.2

^aUnits from Standard (3.5% NFDM bologna)

Tensile strength determination. From the results of an analysis of variance, Table XIV, it was established that treatments differed significantly. Since the interaction of treatment x replication showed sig-

nificance when tested with the first order error term, the interaction was used as the error term for testing treatments and replications.

Table XIV. Analysis of variance of tensile strength of bologna from comparison I

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	4	1,688,974.24	422,243.56	5.51**
Replication	1	163,377.64	163,377.64	2.13
Tr. x rep.	4	289,658.16	72,414.54 ^b	16.99**
Error	90	383,492.40	4,261.03 ^a	
Total	99	2,525,502.44		

**Significant at 1% level

^aError term for Tr. x rep. interaction

^bError term for Treatments and Replications

It can be seen from the values listed for trials 1 and 2 in Table XV that only the 3.5 percent treatment of trial 1 was not in a consistent order of magnitude. This variance was believed responsible for the significant interaction. On further analysis, it was established that differences between treatments were highly significant with the exception of the 3.5 and ten percent treatments. From this it could be concluded that either the 3.5 or ten percent non-fat dry milk treatments would provide about equal tensile strength to the bologna.

Table XV. Tensile strength of bologna from comparison I as influenced by treatment

Treatment % NFDM	Trial 1	Trial 2	Mean values ranked	$\bar{X}$ -198	$\bar{X}$ -319	$\bar{X}$ -421	$\bar{X}$ -508
3.5	430	685	558	360**	239**	137**	50
10	513	504	508	310**	189**	87**	
15	363	479	421	223**	102**		
Control	272	366	319	121**			
20	224	171	198				

**Significant at 1% level

Flavor evaluation. The results of an analysis of variance for flavor preference scores are presented in Table XVI. It was established that differences in scores between treatments were highly significant. According to the results of the studentized range test, Table XVII, the 3.5 and ten percent treatments were preferred over the 20 percent treatment at the one percent level of significance while the control and 15 percent treatments differed from the 20 percent treatment at the 5% level of significance. The other treatments did not differ significantly, but the mean values indicated a slight preference for bologna containing either 3.5 or ten percent non-fat dry milk. These results are not inconsistent with those reported by Cook and Day (1947) and the American Dry Milk Institute (1953) which stated that as much as eight to ten percent non-fat dry milk could be added to sausages to produce a flavorful product. Gerrard (1955) also reported that a flavorful sausage product could be produced through the addition of non-fat dry milk.

Table XVI. Analysis of variance of flavor preference of bologna in comparison I

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	4	76.20	19.05	12.29**
Replication	1	0.02	0.02	<1.0
Tr. x rep.	4	2.18	0.54	<1.0
Error	140	216.93	1.55	
Total	149	295.33		

**Significant at 1% level

Juiciness evaluation. In the first comparison, the evaluation of juiciness was varied from the general procedure as outlined previously.

For the first trial, juiciness was combined with texture-tenderness and will be discussed later. It was believed that the three factors could not be satisfactorily evaluated on an individual basis due to interdependencies; however, due to contract arrangements, it was necessary to evaluate juiciness separately in later trials. The results of the second trial are presented in Table XVIII.

Table XVII. Flavor preference scores for bologna from comparison I as influenced by treatment

Treatment % NFDM	Mean value	$\bar{X}$ -5.5	$\bar{X}$ -6.6	$\bar{X}$ -6.7	$\bar{X}$ -7.3
3.5	7.5	2.0**	0.9	0.8	0.2
10.0	7.3	1.8**	0.7	0.6	
15.0	6.7	1.2*	0.1		
Control	6.6	1.1*			
20.0	5.5				

*Significant at 5% level

**Significant at 1% level

The control batch was used as the standard and differences are expressed relative to this standard. The ten and 20 percent treatments differed significantly from the control batch while the 3.5 and 15 percent treatments closely approached significance when compared with the control batch. As has been pointed out by Swift et al. (1954), juiciness is influenced by variations in moisture and fat content and as a result of this, differences observed here may not be due solely to the non-fat dry milk treatments.

Table XVIII. Analysis of juiciness differences of bologna from comparison I using a one-factor range test

Treatment % NFDM	Mean value	Sums ranked	Sum-24	Sum-39	Sum-42	Sum-51
10	3.5	52	28**	13	10	1
20	3.4	51	27**	12	9	
15	2.8	42	18	3		
3.5	2.6	39	15			
Control	1.6	24				

**Significant at 1% level

Texture-Tenderness evaluation. Differences in texture-tenderness were analyzed and are presented in Table XIX. The 3.5 percent treatment was employed as the standard for trial 1 of this evaluation and the control batch as standard for trial 2. Differences are relative to these standards and as mentioned previously, the first trial included juiciness as a factor. For the first trial, the panel appeared to detect differences accurately as the mean difference rating given the 3.5 percent treatment (Standard) was 1.1 and a value of 1.0 indicated no difference. The 20 percent treatment showed highly significant differences from all except the 15 percent treatment, which differed at the five percent level. The 15 percent level was significantly different from the 3.5 and ten percent treatments and the control from the 3.5 percent treatment at the one percent level. The ten percent treatment differed from the 3.5 percent at the five percent level of significance. In the second trial, where only texture-tenderness was considered, the 20 percent treatment showed highly significant differences from all other batches except the ten percent treatment, from which it differed at the five percent level of significance. Other differences were not large enough for significance at the five percent level. Here again,

it was reported by Swift et al. (1954), that tenderness of bologna is directly affected by the moisture and fat content. Though the differences observed here would appear to be due primarily to the non-fat dry milk treatments, it may be that other factors which vary with changes in non-fat dry milk are actually responsible for the texture-tenderness of the finished product.

Table XIX. Differences in texture-tenderness scores of bologna from comparison I as determined with a one-factor range test

Treatment % NFDM	Mean value	Sums ranked	Sum-17	Sum-37	Sum-53	Sum-60
<u>Trial 1</u>						
20	5.2	78	61**	41**	25**	18*
15	4.0	60	43**	23**	7	
Control	3.5	53	36**	16		
10	2.5	37	20*			
3.5	1.1	17				
<u>Trial 2</u>			Sum-38	Sum-49	Sum-56	Sum-60
20	6.0	90	52**	41**	34**	30*
10	4.0	60	22	11	4	
15	3.7	56	18	7		
3.5	3.3	49	11			
Control	2.5	38				

*Significant at 5% level

**Significant at 1% level

Investigation of the effects of two levels of non-fat dry milk and four types of meat on the processing and quality characteristics of bologna, Comparison II. This comparison was designed to test the effects of non-fat dry milk when meat of various binding qualities and fat content were employed in bologna formulations.

Percent yield. An analysis of variance revealed highly significant differences between non-fat dry milk treatments, meat treatments, and replications. From the results of the first comparison, it was expected

that differences would occur in the percent yield and between replications. With the wide variety of meat treatments employed, it would have been surprising if differences in meat treatments had not been established as presented in Table XX. The various interactions were non-significant.

Table XX. Analysis of variance of percent yield of bologna from comparison II

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
NFDM	2	11.05	5.52	7.46**
Meat	3	65.53	21.84	29.51**
Replication	1	24.82	24.82	33.54**
NFDM x Meat	6	1.39	0.23	0.31
NFDM x Rep.	2	2.08	1.04	1.41
Meat x Rep.	3	2.74	0.91	1.23
NFDM x Meat x Rep.	6	3.79	0.63	0.85
Error	48	35.59	0.74	
Total	71	146.69		

**Significant at 1% level

With further analysis using the studentized range table, it was established that significant differences existed between individual treatments as presented in Table XXI. The 3.5 and ten percent non-fat dry milk treatment yields were significantly greater than that of the control. The 3.5 and ten percent treatment yields were not significantly different and thus might indicate that a maximum yield would not require as much as ten percent non-fat dry milk. These results serve to point out the improved water-binding effect to be expected in sausage from the addition of non-fat dry milk as has been suggested by the American Dry Milk Institute (1953). It was indicated that up to ten percent could be used to advantage with respect to yield. Non-fat dry milk appeared to fulfill the requirements of a good sausage binder as described by Kraybill

(1955) and Wilson (1960) who stated that binders serve the purpose of absorption of moisture during chopping and retain this moisture throughout processing. The analysis revealed that the high fat treatment gave a significantly greater yield than did the low fat or low binding formulations. It was also established that significantly greater yields were obtained with the regular binding formulation than with the low binding or low fat treatments. Also, the low binding treatment differed significantly from the low fat treatment. As pointed out earlier by Gerrard (1955), as the fat content was decreased, more moisture was present.

Table XXI. Percent yield of bologna from comparison II as influenced by NFDM and meat of different binding qualities

% NFDM	Mean (4 batches/trial)		Means ranked (Av. of 8 batches)	$\bar{X}$ -92.92	$\bar{X}$ -93.58
	Trial 1	Trial 2			
3.5	94.34	93.36	93.85	0.93**	0.27
10.0	94.02	93.14	93.58	0.66*	
Control	93.74	92.10	92.92		

Type of Meat	Mean (3 batches/trial)		Means ranked (6 batches)	$\bar{X}$ -92.02	$\bar{X}$ -93.18	$\bar{X}$ -94.13
	Trial 1	Trial 2				
High fat	95.37	93.58	94.48	2.46**	1.30**	0.35
Regular binding	94.71	93.55	94.13	2.11**	0.95**	
Low binding	93.53	92.83	93.18	1.16**		
Low fat	92.54	91.50	92.02			

**Significant at 1% level

*Significant at 5% level

As the percent moisture in the raw ingredients is increased, a lower yield can be expected due to greater cooking losses.

The mean values for each trial are presented in Table XXI and serve to explain the significance between replications since the response for each treatment was not in the same relation for both replications.

Heat treatment. The results showed a greater effect in rate of heat penetration due to type of meat than the addition of 3.5 or ten percent non-fat dry milk. The treatments containing a high percent fat heated faster than all other treatments and they were followed by the regular binding, low binding, and low fat treatments. From this it appeared that the fat content played an important role in heat transfer. Since animal fats melt below the temperatures used here, it would be expected that their presence would result in a faster heat transfer (convection) whereas with less fat, conduction heating was more dominant. As in the first comparison, maximum temperature differences between batches were observed after the first 30-45 minutes of heating. The treatments varied as much as 16°F. at this time but the treatments were not consistent between replications.

Percent shrink. An analysis of variance of percent shrink revealed that neither non-fat dry milk treatments nor type of meat had a significant influence on shrinkage over a seven day period. These results are presented in Table XXII and are consistent with the results obtained for non-fat dry milk treatments from the first comparison. As in the first comparison, these results are not in accordance with results reported by the American Dry Milk Institute (1953). It was stated that less shrink was obtained where non-fat dry milk was added to the sausage formulation. It should be noted, however, that they may have been reporting results in terms of shrinkage during cooking rather than storage after processing.

Table XXII. Analysis of variance of percent shrink (7 da.) of bologna from comparison II

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
NFDM-Tr.	2	1.03	0.52	2.36
Meat-Tr.	3	0.97	0.32	1.45
Replication	1	0.61	0.61	2.77
NFDM x Meat	6	0.14	0.02	<1.0
NFDM x Rep.	2	0.15	0.08	<1.0
Meat x Rep.	3	0.51	0.17	<1.0
NFDM x Meat x Rep.	6	1.32	0.22	
Total	23	4.73		

Percent moisture. The results of an analysis of variance of percent moisture are presented in Table XXIII. This analysis revealed that type of meat had the greatest influence on moisture content and was the major treatment responsible for significant differences. This is in agreement with the findings reported by Gerrard (1955) in which he stated that variations in moisture content are due to the amount of water added with the binder and the amount of moisture in the meat used. As the fat content was increased in the meat, the moisture and protein were observed to have decreased. He also indicated that meat was the most difficult variable to control. In addition to variations between meat treatments, significant variations were observed between replications, in the NFDM x Meat as well as the Meat x Rep. interactions.

The results of the studentized range test, Table XXIV, showed that all treatments differed significantly with respect to percent moisture. As one would expect, the moisture content was inversely related to the fat content of the formulations used. It also can be seen from the trial means in Table XXIV that the percent moisture for the low fat, low binding, and regular binding treatments was greater for the first

trial, whereas this was reversed in the high fat treatment. It was concluded that the significance of the Meat x Rep. interaction was due to the response of the high fat treatment.

Table XXIII. Analysis of variance of percent moisture of bologna from comparison II

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
NFDM-Tr.	2	1.86	0.93	<1.0
Meat-Tr.	3	433.00	144.33	83.47**
Replication	1	2.01	2.01	8.38*
NFDM x Meat	6	8.98	1.50	6.25*
NFDM x Rep.	2	2.01	1.00 ^c	4.17
Meat x Rep.	3	5.24	1.75 ^b	7.29*
NFDM x Meat x Rep.	6	1.46	0.24 ^a	
Total	23	453.14		

*Significant at 5% level

**Significant at 1% level

^aError term for all interactions and replications

^bError term for Meat-Tr.

^cError term for NFDM-Tr.

Table XXIV. Percent moisture of bologna from comparison II as influenced by meat of different binding qualities

Meat treatment	Mean (3 batches/trial)		Means ranked (6 batches)			
	Trial 1	Trial 2		$\bar{X}$ -60.11	$\bar{X}$ -63.36	$\bar{X}$ -68.32
Low fat	71.71	70.39	71.05	10.94**	7.69**	2.73*
Low binding	68.54	68.10	68.32	8.21**	4.96**	
Regular binding	64.09	62.64	63.36	3.25*		
High fat	59.67	60.56	60.11			

*Significant at 5% level

**Significant at 1% level

The interaction of NFDM x Meat showed significance since the relationship between mean values for the NFDM and Meat Treatments were not

consistent in all cases. These values are presented in Table XXV. It can be observed that with increased non-fat dry milk for any given meat treatment, the response in percent moisture did not change in any apparent order, thus causing the significant interaction.

Table XXV. Mean values for percent moisture in bologna from comparison II as influenced by meat of different binding qualities

Type of meat	Percent NFDM		
	Control	3.5	10.0
Regular binding	63.09	63.90	63.16
Low fat	72.20	71.26	69.69
High fat	59.22	60.38	60.74
Low binding	68.76	68.42	67.78

Percent protein. From the results of this comparison, an analysis of variance (Table XXVI) revealed that non-fat dry milk treatments of 3.5 and ten percent did not significantly increase or decrease the protein content of bologna. This is in agreement with the results obtained in the first comparison. It was observed, however, that the type of meat had a highly significant effect upon the protein content. This was in accordance with expectations due to the wide variation in the type of meat used and the various lean to fat ratios employed. With the larger amounts of lean, the protein content would of necessity be greater.

According to the results of the studentized range test, it was established that the low fat formulation had significantly more protein than any other type of meat formulation employed. The low binding formulation, which contained pork hearts, had significantly more protein than the high fat formulation but was not significantly different from

the treatment containing meat of regular binding quality. The trial means for meat treatments are presented in Table XXVII and show the variation that possibly caused the significance between replications. Difficulty was encountered in producing the same relative response for both replications with the high fat formulation.

Table XXVI. Analysis of variance of percent protein of bologna from comparison II

Source of Variance	Degrees of freedom	Sum of squares	Mean square	F-value
NFDM-Tr.	2	0.17	0.08	<1.0
Meat-Tr.	3	56.01	18.67	44.45**
Replication	1	0.25	0.25	8.33*
NFDM x Meat	6	1.17	0.20	6.67*
NFDM x Rep.	2	0.25	0.12 ^c	4.00
Meat x Rep.	3	1.26	0.42 ^b	14.00**
NFDM x Meat x Rep.	6	0.17	0.03 ^a	
Total	23	59.28		

*Significant at 5% level

**Significant at 1% level

^aError term for all interactions and replications

^bError term for Meat-Tr.

^cError term for NFDM-Tr.

Table XXVII. Percent protein of bologna from comparison II as influenced by meat of different binding qualities

Meat treatment	Mean		Mean ranked (both trials)	$\bar{X}$ -13.93	$\bar{X}$ -14.78	$\bar{X}$ -15.91
	Trial 1	Trial 2				
Low fat	18.06	17.95	18.01	4.08**	3.23**	2.10*
Low binding	16.29	15.52	15.91	1.98*	1.13	
Regular binding	14.99	14.57	14.78	0.85		
High fat	13.69	14.17	13.93			

*Significant at 5% level

**Significant at 1% level

Since the treatment of NFDM x Meat showed significance (Table XXVI) an additional table of mean values, Table XXVIII, has been included to aid in explaining this situation. From this table it can be observed

that the non-fat dry milk treatments did not always respond in the same relation with meat treatments as regards the protein content of the finished product. With the exception of the low fat-ten percent non-fat dry milk average, there appeared to be a definite trend toward a higher percent protein with increased amounts of non-fat dry milk even though the difference was not sufficient to show significance.

Table XXVIII. Mean values for percent protein in bologna from comparison II as influenced by meat of different binding qualities

Type of meat	Percent NFDM		
	Control	3.5	10.0
Regular binding	14.62	14.78	14.94
Low fat	18.19	18.22	17.61
High fat	13.73	13.94	14.12
Low binding	15.66	15.70	16.36

Percent fat. The results of an analysis of variance are presented in Table XXIX. It was established that both the amount of non-fat dry milk added and the meat formulation used produced highly significant effects upon the percent fat in the finished product. In addition, the Meat x Rep. interaction showed significance and thus was used as the error term for testing meat treatments. In order to test for differences between the non-fat dry milk treatments a new error term was derived by combining the three-way interaction and the NFDM x Rep. interaction.

The results of the studentized range test showed that all treatments of non-fat dry milk produced highly significant differences in percent fat. As mentioned earlier in discussion of the first comparison, the percent fat was reduced as the non-fat dry milk was increased and, therefore, significant differences were anticipated (Table XXX). The

Table XXIX. Analysis of variance of percent fat of bologna from comparison II

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
NFDM-Tr.	2	81.65	40.82	127.56**
Meat-Tr.	3	787.60	262.53	96.16**
Replications	1	1.82	1.82	4.44
NFDM x Meat	6	8.61	1.44	3.51
NFDM x Rep.	2	0.08	0.04	<1.0
Meat x Rep.	3	8.19	2.73 ^b	6.66*
NFDM x Meat x Rep.	6	2.45	0.41 ^a	
Total	23	890.40		
Error	8	2.53	0.32 ^c	

*Significant at 5% level

**Significant at 1% level

^aError term for all interactions and replications

^bError term for Meat-Tr.

^cError term for NFDM-Tr.

analysis also revealed significant differences between the fat content of all batches with respect to type of meat employed. This, too, was expected to occur due to the wide variations in the formulations used. The mean values for percent fat of meat treatments are presented in Table XXX to aid in explaining the reason for the significant Meat x Rep. interaction as determined by the analysis of variance of percent fat. The high fat formulation did not respond in the second replication in relation to the response obtained for other formulations. This could have been due to improper estimation of the fat content of the raw ingredients used.

Table XXX. Percent fat of bologna from comparison II as influenced by NFDM and meat of different binding qualities

% NFDM	Means ranked		$\bar{X}$ -11.29		$\bar{X}$ -13.82	
Control	15.79		4.50**		1.97**	
3.5	13.82		2.53**			
10.0	11.29					

Meat treatment	Mean (3 batches/trial)		Means ranked (6 batches)	$\bar{X}$ -5.88		
	Trial 1	Trial 2		$\bar{X}$ -10.93	$\bar{X}$ -16.73	
High fat	21.67	20.32	21.00	15.12**	10.07**	4.27*
Regular binding	15.82	17.64	16.73	10.85**	5.80**	
Low binding	10.39	11.48	10.93	5.05*		
Low fat	5.55	6.21	5.88			

*Significant at 5% level

**Significant at 1% level

pH determinations. The pH values for this comparison are given in Table XXXI according to trials. It can be noted that variation between replications was only 0.2 pH units. The values were generally higher where non-fat dry milk was incorporated into the formulations. This finding is in agreement with the general concept of the action of binding materials as discussed in the first comparison. Swift and Ellis (1954), and Wilson (1960) stated that pH was directly related to the binding properties of muscle tissue, or more specifically, sausage. Hamm (1953) also agrees with this observation.

Color evaluation. Also presented in Table XXXI are values for Color Renotation and the Index of Fading. From the renotation values, it is quite clear that with low fat (high lean) or added pork hearts (low binding) the bologna was more nearly red and as the fat content was increased the color shifted toward the yellow-red or in effect became

lighter in color even though the Color Value was approximately the same for all samples. The values given for the Index of Fading show all samples to be lighter than the standard.

Table XXXI. pH, color renotation and index of fading values of bologna from comparison II as influenced by NFDM and meat of different binding qualities

Treatment	pH value		Renotation value		Index of fading ^a	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
<u>Control</u>						
regular						
binding	6.3	6.2	1.7YR 6.3/3.8	2.9YR 6.4/3.6	+2.55	+3.73
low fat	6.3	6.3	1.0YR 6.4/4.5	1.3YR 6.3/3.9	+5.52	+3.02
high fat	6.4	6.4	1.5 YR 6.3/3.4	2.3YR 6.3/3.6	+2.59	+2.58
low						
binding	6.5	6.5	1.0YR 6.3/4.2	1.1YR 6.3/4.2	+4.62	+4.38
<u>3.5% NFDM</u>						
regular						
binding	6.6	6.4	1.7YR 6.4/4.0	2.4YR 6.3/3.5	+3.16	+2.86
low fat	6.6	6.4	0.8YR 6.3/4.4	1.3YR 6.3/4.1	+5.36	+3.61
high fat	6.3	6.4	1.6YR 6.3/3.6	2.5YR 6.3/3.5	+1.53	+2.97
low						
binding	6.3	6.4	1.3YR 6.4/4.4	1.2YR 6.3/4.2	+4.79	+4.27
<u>10.0% NFDM</u>						
regular						
binding	6.4	6.4	1.9YR 6.3/3.8	2.5YR 6.4/3.7	+2.95	+3.49
low fat	6.4	6.4	1.2YR 6.4/4.8	1.3YR 6.3/3.9	+6.42	+3.05
high fat	6.4	6.3	1.7YR 6.3/3.7	2.5YR 6.3/3.3	+2.07	+3.35
low						
binding	6.3	6.3	1.0YR 6.3/4.2	1.2YR 6.3/4.3	+4.62	+4.40

^aUnits from standard (3.5% NFDM bologna)

Tensile strength determinations. The results of an analysis of variance of tensile strength of bologna (Table XXXII) showed a significant difference between non-fat dry milk treatments and meat treatments. The three-way interaction was significant when tested with the error term and was thus used for testing all interactions, replications, and treatments.

Table XXXII. Analysis of variance of tensile strength of bologna from comparison II

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
NFDM-Tr.	2	3,731,511.2	1,865,755.6	24.98**
Meat-Tr.	3	2,140,603.7	713,534.6	12.63**
Replications	1	47,742.6	47,742.6	<1.0
NFDM x Meat	6	742,929.5	123,821.6	1.66
NFDM x Rep.	2	182,169.9	91,085.0	1.22
Meat x Rep.	3	60,495.8	20,165.3	<1.0
NFDM x Meat x Rep.	6	448,094.7	74,682.5 ^b	7.73**
Error	216	1,828,564.7	8,465.6 ^a	
Total	239	9,182,112.1		

*Significant at 5% level

**Significant at 1% level

^aError term for 3-way interaction

^bError term for all two-way interactions and NFDM-Tr., Meat-Tr., Replications

From the results presented in Table XXXIII, it was observed that the addition of non-fat dry milk increased significantly the tensile strength of bologna. As noted in the first comparison, there was no real difference in tensile strength between the 3.5 and ten percent treatments. With respect to type of meat used, it was found that the low fat treatment had a significantly greater tensile strength than all other types of meat employed. There were no differences noted between the other meat treatments. These results are in accordance with what would be expected. As the fat content was increased, the amount of lean present was reduced and this in turn reduced the tensile strength of the bologna. Though not significant, it was even more interesting to note the effect that binding quality of the meat had on tensile strength of bologna. The lowest mean value obtained for tensile strength of bologna was with the low binding formulation. Thus, the binding quality of the meat may actually have a greater influence than the fat content.

Table XXXIII. Tensile strength values of bologna from comparison II as influenced by NFDM and meat of different binding qualities

Treatment	Means ranked	$\bar{X}$ -406	$\bar{X}$ -636
<u>% NFDM</u>			
3.5	695	289**	59
10.0	636	230**	
Control	406		

Type of meat	Means ranked	$\bar{X}$ -509	$\bar{X}$ -521	$\bar{X}$ -546
Low fat	741	232**	220**	195**
High fat	546	37	25	
Regular binding	521	12		
Low binding	509			

**Significant at 1% level

In order to help explain the significant three-way interaction obtained by the analysis (Table XXXII) an additional table is presented, Table XXXIV, which includes the mean values for tensile strength of all batches. The failure of all batches to respond in the same manner for each treatment with respect to trials was considered the reason for the significant interaction.

Table XXXIV. Mean tensile strength values of bologna from comparison II as influenced by NFDM and meat of different binding qualities

Type of meat	Control	3.5% NFDM	10.0% NFDM	Mean		Mean
				Trial 1	Trial 2	
Regular binding	408 ^a	628	526	493	548	521
Low fat	466	851	906	715	767	741
High fat	410	697	530	531	561	546
Low binding	339	604	584	521	497	509
<u>Mean</u>						
Trial 1	385	651	659			
Trial 2	426	739	614			
Mean	406 ^b	695	636			

^aMean value of two trials/treatment (20 strips of bologna)

^bMean value of 80 strips of bologna

Flavor evaluation. Results of an analysis of variance of flavor preference scores are presented in Table XXXV. It was established that the addition of 3.5 and ten percent non-fat dry milk did not cause significant flavor differences in bologna. Likewise, it was found that variations in the type of meat used, with respect to fat content and binding quality, did not yield significant flavor differences. Based on these findings, with no apparent difference between the 3.5 and ten percent non-fat dry milk treatments, the third comparison was conducted to compare the higher level of non-fat dry milk with comparable treatments of other binders.

Table XXXV. Analysis of variance of flavor preference scores of bologna from comparison II

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
NFDM-Tr.	2	4.31	2.16	1.80
Meat-Tr.	3	5.36	1.79	1.50
Replications	1	3.40	3.40	2.83
NFDM x Meat	6	5.89	0.98	<1.0
NFDM x Rep.	2	2.64	1.32	1.10
Meat x Rep.	3	0.41	0.14	<1.0
NFDM x Meat x Rep.	6	5.52	0.92	<1.0
Error	336	402.00	1.20	
Total	359	429.53		

Juiciness evaluation. Juiciness difference scores were analyzed and the results are presented in Table XXXVI. The addition of 3.5 percent non-fat dry milk caused a significant decrease in juiciness when compared with the control, while with ten percent non-fat dry milk the decrease in juiciness was less marked. This was likely due to the greater percent added moisture where higher level of non-fat dry milk

was added. Swift et al. (1954) reported increased juiciness and tenderness with increased fat and moisture with the latter having the greater effect.

It can be observed from Table XXXVI that variation in the fat content caused significant changes in juiciness. All treatments were significantly more juicy than the low fat meat treatment. The use of low binding meats, such as hearts, failed to produce significant differences in juiciness.

Table XXXVI. Analysis of juiciness difference scores of bologna from comparison II using a two-factor range test

Treatment	Mean values	Sums ranked	Sum-946	Sum-1000
<u>% NFDM</u>				
Control	8.9	1,063	117*	63
10	8.3	1,000	54	
3.5	7.9	946		
<u>Type of meat</u>				
High fat	7.1	856	Sum-568 288**	Sum-777 79 Sum-808 48
Regular binding	6.7	808	240**	31
Low binding	6.5	777	209*	
Low fat	4.7	568		

*Significant at 5% level

**Significant at 1% level

Texture-Tenderness evaluation. The results of an analysis of the difference scores for texture-tenderness, Table XXXVII, revealed no significant differences due to the presence of 3.5 or ten percent non-fat dry milk or variations in the type of meat used. The mean values, also presented in Table XXXVII, indicated that the addition of non-fat dry milk yielded bologna of lower texture-tenderness values than the control.

While significant differences due to variations in type of meat were present, it should be pointed out that fat content appeared to play an important role with respect to texture-tenderness of bologna, increasing with an increased fat content.

Table XXXVII. Analysis of texture-tenderness difference scores of bologna from comparison II using a two-factor range test

Treatment	Mean values	Sums ranked	Sum-996	Sum-1021
<u>% NFDM</u>				
Control	8.7	1,046	50	25
10	8.5	1,021	25	
3.5	8.3	996		
<u>Type of Meat</u>				
High fat	7.2	869	Sum-616 253 ^a	Sum-779 90
Low binding	6.7	799	183	20
Regular binding	6.5	779	163	
Low fat	5.1	616		

^a255 required for significance at 5% level

Investigation of the effects of non-fat dry milk, soya grits, phosphate, and meat of different binding qualities upon the processing and quality characteristics of bologna, Comparison III. After establishing the various effects of non-fat dry milk in the first and second comparisons, it was desired to compare non-fat dry milk with other sausage binders. Soya grits and non-fat dry milk were employed at a rate of ten percent. A phosphate mixture (25% Kurrol's salt and 75% tetrasodiumpyrophosphate) was added at the rate of 4.7 ounces per 100 pounds of meat. In addition, as in the second comparison, meat of different binding qualities were tested with these binders.

Percent yield. From the results of an analysis of variance, Table XXXVIII, it was established that significant differences did exist in "out of cook" yield due to type of binder used as well as type of meat. It should also be noted that variation between replications was found to be significant.

Table XXXVIII. Analysis of variance of percent yield of bologna from comparison III

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Binder-Tr.	3	9.42	3.14	2.93*
Meat-Tr.	3	62.25	21.75	20.33**
Replication	1	6.60	6.60	6.17*
NFDM x Meat	9	6.39	0.71	<1.0
NFDM x Rep.	3	3.35	0.45	<1.0
Meat x Rep.	3	3.32	1.11	1.04
NFDM x Meat x Rep.	9	7.22	0.80	<1.0
Error	64	68.26	1.07	
Total	95	167.81		

*Significant at 5% level

**Significant at 1% level

Further analysis (Table XXXIX) revealed that the phosphate binder produced a significantly greater yield than the control. This finding was not in agreement with the results reported by Wilson (1954) and (1960); however, they were in agreement with the results of Swift and Ellis (1956), Tarladgis (1959), Bendall (1954), and Tims and Watts (1958), who reported increased moisture and juice retention during cooking through the use of phosphates. This effect had been observed with primal cuts by Brissey (1952) and Dopner (1949).

None of the other treatments differed significantly even though the mean values presented in Table XXXIX show slight increases in percent yield where the binders were employed. From the description of sausage

binders by Kraybill (1955) and Wilson (1960) where binders are described as serving the purpose of absorbing and retaining moisture throughout processing, it would appear that of the binders tested the phosphate mixture most nearly fits this description.

While the type of binder had a measurable effect on juice and/or moisture retention, the more noticeable effects were due to variations in type of meat employed. It was found that the regular binding and high fat formulations produced significantly greater yields than either the low binding or low fat formulations. This would find agreement with the work of Dopner (1949), in which he stated that such factors as meat type, degree of chop, and handling procedures played a more important role in moisture retention than the addition of a phosphate binder. It should be pointed out that on the basis of added moisture, the phosphate treatment contained only 25 percent added moisture as compared with 25 percent in the control and about 47.4 percent where non-fat dry milk and soya grits were employed. When taking into account the fact that the latter two treatments contained about 17.4 percent more added moisture, yet yielded within 0.5 percent that of the phosphate treatment, it could be assumed that under conditions of equal added moisture the results would likely have been in favor of soya grits and/or non-fat dry milk. This difference in formulation might possibly account for the lack of agreement with Cook and Day (1947), Pahlke (1944), and the American Dry Milk Institute (1953), who reported increased benefits through the use of non-fat dry milk and Gerrard (1955), who indicated soya products were known for their ability to absorb and retain moisture in sausage.

Table XXXIX. Percent yield of bologna from comparison III as influenced by different binders

Treatment	Means		Mean ranked	$\bar{X}$ -93.26	$\bar{X}$ -93.71	$\bar{X}$ -93.80
	Trial 1	Trial 2				
Binder						
Phosphate	94.34	93.84	94.09	0.83*	0.38	0.29
10% Soya grits	93.88	93.71	93.80	0.54	0.09	
10% NFDM	94.10	93.32	93.71	0.45		
Control	93.64	92.88	93.26			

Type of meat	Means		Mean ranked	$\bar{X}$ -92.69	$\bar{X}$ -93.10	$\bar{X}$ -94.34
	Trial 1	Trial 2				
Regular binding	95.05	94.40	94.72	2.03**	1.62**	0.38
High fat	94.38	94.30	94.34	1.65**	1.24**	
Low binding	93.48	92.73	93.10	0.41		
Low fat	93.08	92.32	92.69			

*Significant at 5% level

**Significant at 1% level

Heat treatment. The heat process data showed some grouping of the treatments, with the greatest differences being due to the type of meat employed. The low fat treatments had the highest heat transfer rate, followed by low binding, regular binding, and the high fat treatments. As in the preceeding comparisons, the results obtained between replications were not entirely consistent. This could have been due to air pockets or failure to center the thermocouple accurately within the bologna. The maximum difference observed between treatments was approximately 30°F.

Percent shrinkage. As given in Table XL, the results of an analysis of variance of percent shrink over a seven day storage period following processing showed that significant differences existed between binder treatments and between replications.

Table XL. Analysis of variance of percent shrink (7 da.) of bologna from comparison III

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Binder-Tr.	3	5.97	1.99	6.63*
Meat-Tr.	3	1.81	0.60	2.00
Replication	1	5.78	5.78	19.27**
Binder x Meat	9	1.98	0.22	<1.0
Binder x Rep.	3	1.00	0.33	1.10
Meat x Rep.	3	0.08	0.03	<1.0
Binder x Meat x Rep.	9	2.71	0.30	
Total	31	19.33		

*Significant at 5% level

**Significant at 1% level

It would be normal to expect that batches which had the greatest yield out of cook would also show the greatest percent shrinkage due to the increased amount of moisture present. This was, for the most part, true according to the results presented in Table XLI. The phosphate treatment gave a significantly greater shrink than the control or non-fat dry milk treatments. Soya grits gave significantly greater shrinkage than the non-fat dry milk treatment. The most remarkable finding, while not significant, was the reversal of the control and non-fat dry milk treatments. The control had a lower yield but a greater shrink than the non-fat dry milk treatment as determined by the mean values. The mean values as presented by trials show the failure of the treatments to respond in the same relation between trials which was responsible for the significant difference between replications shown by the analysis of variance.

Table XLI. Percent shrink (7 da.) of bologna from comparison III as influenced by different binders

Treatment	Mean		Means ranked	$\bar{X}$ -7.91	$\bar{X}$ -8.40	$\bar{X}$ -8.75
	Trial 1	Trial 2				
Phosphate	8.34	9.80	9.08	1.17**	0.68*	0.33
10% Soya grits	8.45	9.05	8.75	0.84*	0.35	
Control	7.18	8.72	8.40	0.49		
10% NFDM	7.56	8.26	7.91			

*Significant at 5% level

**Significant at 1% level

Percent moisture. The results of an analysis of variance, Table XLII, showed that the type of binder employed significantly affected the percent moisture. Also, the types of meat used were responsible for significant differences with regard to the moisture content of the bologna. Other differences noted were between replications and also the Binder x Meat interaction.

Table XLII. Analysis of variance of percent moisture of bologna from comparison III

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Binder-Tr.	3	13.91	4.64	27.29*
Meat-Tr.	3	623.47	207.82	314.89**
Replication	1	6.69	6.69	55.75**
Binder x Meat	9	11.91	1.32	11.00**
Binder x Rep.	3	0.51	0.17 ^c	1.42
Meat x Rep.	3	1.97	0.66 ^b	5.50*
Binder x Meat x Rep.	9	1.10	0.12 ^a	
Total	31	659.56		

* Significant at 5% level

**Significant at 1% level

^aError term for all interactions and replications

^bError term for Meat-Tr.

^cError term for Binder-Tr.

On further analysis, it was found that the non-fat dry milk, phosphate, and control treatments all contained significantly more moisture than the soya grits treatment, but did not differ between themselves. It might be well to point out that even though the added moisture was the same for the non-fat dry milk and soya treatments, the former contained approximately two percent more moisture (Table XLIII) and from this one could conclude possible improved water-holding through the use of non-fat dry milk over soya grits. Phosphates showed this same advantage, but as mentioned previously, less added moisture was used in the phosphate formulation.

Table XLIII. Percent moisture of bologna from comparison III as influenced by meat of different binding qualities

Treatment	Means ranked	$\bar{X}$ -62.24	$\bar{X}$ -63.37	$\bar{X}$ -63.59
Binder				
10% NFDM	64.02	1.78**	0.65	0.43
Phosphate	63.59	1.35**	0.22	
Control	63.37	1.13*		
10% Soya grits	62.24			
		$\bar{X}$ -58.34	$\bar{X}$ -59.78	$\bar{X}$ -65.99
Type of meat				
Low fat	69.10	10.76**	9.32**	3.11
Low binding	65.99	7.65*	6.21*	
Regular binding	59.78	1.44		
High fat	58.34			

*Significant at 5% level

**Significant at 1% level

The type of meat was found to influence the percent moisture considerably. As in the second comparison, the low fat and low binding treatments yielded bologna that had significantly more moisture than the regular binding or high fat treatments. These findings were as expected

when the moisture content of the meat used was considered.

In order to show some of the variation responsible for significance of the Binder x Meat interaction and between replications, the mean values for percent moisture are presented in Table XLIV. The variation present between treatments and replications serves again to point out the difficulty in obtaining meat of uniform composition. This has been pointed out earlier by Gerrard (1955) and Dopner (1949).

Table XLIV. Mean values of percent moisture of bologna from comparison III as influenced by different binders

Type of Meat	Control	10% NFDM	10% Soya grits	(4.7 oz/100 lb. meat) phosphate	Mean		Mean
					Trial 1	Trial 2	
Regular							
binding	59.02 ^a	60.86	59.36	59.86	60.61	58.94	59.78
Low fat	70.11	68.94	67.24	70.13	69.33	68.88	69.10
High fat	57.92	59.85	57.69	57.92	58.58	58.10	58.34
Low binding	66.42	66.43	64.66	66.45	66.52	65.46	65.99
Mean							
Trial 1	63.96	64.60	62.57	63.91			
Trial 2	62.77	63.44	61.90	63.26			
Mean	63.37	64.02	62.24	63.59			

^aMean value of two trials/treatment

Percent protein. Results of the analysis of variance of percent protein are presented in Table XLV. It was established that significant differences existed between types of binders, types of meat, and replications. The three-way interaction was used as the error term for testing all other interactions and replications while the Meat x Rep. interaction was used for testing meat treatments and the Binder x Rep. interaction was used for testing the binder treatments.

Table XLV. Analysis of variance of percent protein of bologna from comparison III

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Binder-Tr.	3	25.84	8.61	43.05**
Meat-Tr.	3	75.00	25.00	55.56**
Replication	1	0.81	0.81	10.12*
Binder x Meat	9	1.15	0.13	1.62
Binder x Rep.	3	0.59	0.20 ^c	2.50
Meat x Rep.	3	1.34	0.45 ^b	5.62*
Binder x Meat x Rep.	9	0.71	0.08 ^a	
Total	31	105.44		

*Significant at 5% level

**Significant at 1% level

^aError term for all interactions and replications

^bError term for Meat-Tr.

^cError term for Binder-Tr.

The results of further analysis, Table XLVI, revealed that the soya grits treatment produced bologna having significantly more protein than the non-fat dry milk, phosphate, or control treatments. This would be expected due to the low moisture content evidenced in the earlier discussion. With reference to the type of meat used, it was found that the low fat (high lean) treatment contained significantly more protein than all other treatments. Also, that the low binding treatment contained more protein than either the regular binding or high fat treatments. This was anticipated from the results obtained in the second comparison.

The mean values for percent protein are given in Table XLVII in order to show the variation observed between trials. The phosphate treatment did not respond for both trials in the same relation to the other treatments which may have given rise to the significant difference between replications as determined by the analysis of variance of percent protein.

Table XLVI. Percent protein of bologna from comparison III as influenced by different binders

Treatment	Means ranked	$\bar{X}$ -14.86	$\bar{X}$ -15.04	$\bar{X}$ -15.07
Type of binder				
10% Soya grits	17.06	2.20**	2.02**	1.99**
10% NFDM	15.07	0.21	0.03	
Control	15.04	0.18		
Phosphate	14.86			

Type of meat	Mean (4 batches/ trial)		Means ranked (8 batches)	$\bar{X}$ -13.88	$\bar{X}$ -14.44	$\bar{X}$ -15.88
	Trial	Trial				
	1	2				
Low fat	17.33	18.34	17.84	3.96**	3.40**	1.96**
Low binding	15.77	15.98	15.88	2.00*	1.44*	
Regular binding	14.40	14.48	14.44	0.56		
High fat	13.89	13.86	13.88			

*Significant at 5% level

**Significant at 1% level

Table XLVII. Mean values of percent protein of bologna from comparison III as influenced by different binders

Type of meat	Control	10% NFDM	10% Soya grits	(4.7 oz./100 lbs. meat) Phosphate	Mean		
					Trial 1	Trial 2	Mean
Regular binding	13.85	14.20	15.93	13.79	14.40	14.48	14.44
Low fat	17.56	16.97	19.30	17.52	17.33	18.34	17.84
High fat	13.20	13.66	15.57	13.07	13.89	13.86	13.88
Low binding	15.54	15.47	17.44	15.07	15.77	15.98	15.88

Mean

Trial 1	14.72	14.84	17.00	14.92
Trial 2	15.35	15.30	17.20	14.81
Mean	15.04	15.07	17.06	14.86

Percent fat. The results of the analysis of variance of percent fat are presented in Table XLVIII. From the results obtained and already discussed for the third comparison, it could be expected that such factors as percent moisture and protein would have considerable influence upon the fat content. Also, on the basis of the results obtained for the first and second comparisons it was expected that significant differences would exist between the different binders and between the various types of meat used. This was found to be the case in the third comparison as well, since the type of binders and type of meat both indicated significant differences. Here again, it was noted that replications differed significantly as well as the binder x meat interaction. Since this interaction showed the largest mean square, it was used as the error term for testing binder and meat treatments. Generally speaking, the response of the binder treatments was not in the same magnitude with respect to meat treatments, which gave rise to the significant interaction. This was anticipated due to the difficulty in maintaining constant composition of the raw ingredients.

Table XLVIII. Analysis of variance of percent fat of bologna from comparison III

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Binder-Tr.	3	180.30	60.10	27.70**
Meat-Tr.	3	1,125.12	375.04	172.83**
Replication	1	6.98	6.98	19.94**
Binder x Meat	9	19.54	2.17 ^b	6.20**
Binder x Rep.	3	0.13	0.04	<1.0
Meat x Rep.	3	1.38	0.46	1.31
Binder x Meat x Rep.	9	3.13	0.35 ^a	
Total	31	1,336.58		

**Significant at 1% level

^aError term for all interactions and replications

^bError term for Binder-Tr. and Meat-Tr.

The results of a further analysis, Table XLIX, showed that the control and phosphate treatments had significantly higher fat contents than either the ten percent soya grits or non-fat dry milk treatments. Significant differences were not observed between the control and phosphate treatments or the soya grits and non-fat dry milk treatment. From a knowledge of the initial meat formulations, these results would be expected since in both the soya grits and non-fat dry milk treatments, the ingredient added was substituted for a portion of the meat. Substitutions were not made where phosphate was added as the binder. On the basis of type of meat used in the formulations and from the results of earlier comparisons, it was anticipated that differences would occur between treatments. The results of this comparison showed all treatments to differ significantly from one another with respect to fat content.

Table XLIX. Percent fat of bologna from comparison III as influenced by various binders

Treatment	Mean	$\bar{X}$ -13.39	$\bar{X}$ -13.66	$\bar{X}$ -18.01
<u>Type of binder</u>				
Control	18.51	5.12**	4.85**	0.50
Phosphate	18.01	4.62**	4.35**	
10% Soya grits	13.66	0.27		
10% NFDM	13.39			
<u>Type of meat</u>		$\bar{X}$ -7.72	$\bar{X}$ -12.89	$\bar{X}$ -20.44
High fat	22.53	14.81**	10.64**	2.09*
Regular binding	20.44	12.72**	7.55**	
Low binding	12.89	5.17**		
Low fat	7.72			

*Significant at 5% level

**Significant at 1% level

The mean values for percent fat of bologna from the third comparison are given in Table L to show where the variation occurred between trials

and treatments which in part was responsible for the significant binder x meat treatment and for the significance between replications.

Table L. Mean values of percent fat of bologna from comparison III

Type of meat	Control	10% NFDM	10% Soya Grits	Phosphate (4.7 oz./100 lbs. meat)	Mean		Mean
					Trial 1	Trial 2	
Regular binding	24.04	17.66	16.98	23.08	19.60	21.28	20.44
Low fat	9.19	6.23	6.66	8.81	7.69	7.76	7.72
High fat	25.75	18.96	19.96	25.45	22.11	22.94	22.53
Low binding	15.04	10.73	11.06	14.72	12.30	13.47	12.89
Mean							
Trial 1	10.54	12.85	13.30	17.53			
Trial 2	11.48	13.94	14.04	18.50			
Mean	18.51	13.39	13.66	18.01			

pH determination. The results obtained for the pH values of the various treatments are presented in Table LI. It is readily apparent from these results that the type of meat used had only slight effects upon the pH of the finished product whereas more striking changes were noted due to the addition of non-fat dry milk, soya grits, and phosphate. These additives all increased the pH of bologna by 0.1 to 0.4 units with phosphate and soya grits showing the greatest changes from the control. These findings are in agreement with the results reported by earlier workers in this field who have studied water-binding and pH in sausage product.

Color evaluation. Also presented in Table LI are the Color Renotation and Index of Fading Values. As in the second comparison, the effect of type of meat is in evidence here. The low binding and low-fat treatments yielded bologna having more redness, whereas the high fat and regular binding treatments approached the yellow-red and the color was

less concentrated on the basis of chroma values and thus appeared lighter as evidenced by the higher value (intermediate number). The Index of Fading values represent the deviation from the standard with the positive (+) sign representing a color lighter than the standard.

Table LI. pH, color renotation, and index of fading values of bologna from comparison III

Treatment	pH values		Color renotation		Index of fading ^B	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
<u>Control</u>						
Regular binding	6.4	6.4	2.0YR 6.4/3.3	3.2YR 6.2/3.2	+3.17	+3.61
Low fat	6.4	6.3	1.8YR 6.0/3.7	2.5YR 5.9/3.6	-0.96	-2.56
High fat	6.4	6.4	2.0YR 6.6/3.2	2.8YR 5.9/3.2	+4.39	-3.27
Low binding	6.4	6.4	1.5 YR5.8/3.8	2.6YR 5.7/3.5	-2.46	-3.74
<u>10% NFDM</u>						
Regular binding	6.5	6.4	3.2YR 5.9/3.0	3.2YR 5.9/2.8	-4.83	-4.85
Low fat	6.5	6.4	1.7YR 5.9/3.5	2.5YR 5.9/3.4	-1.34	-2.86
High fat	6.6	6.5	2.9YR 6.4/3.2	3.0YR 5.8/2.9	+4.75	-4.98
Low binding	6.6	6.5	1.7YR 5.8/3.7	3.2YR 5.9/3.5	-2.37	-3.56
<u>10% Soya grits</u>						
Regular binding	6.7	6.5	4.3YR 6.0/3.6	5.0YR 5.9/3.3	-4.43	-6.20
Low fat	6.6	6.5	4.0YR 5.6/3.8	3.8YR 5.7/3.7	-7.33	-6.32
High fat	6.7	6.5	4.5YR 6.2/3.4	5.3YR 5.9/3.2	+5.12	-6.50
Low binding	6.7	6.6	3.5YR 5.6/3.9	4.5YR 5.3/3.9	-6.71	-10.34
<u>Phosphate^a</u>						
Regular binding	6.8	6.7	2.8YR 6.3/3.5	3.9YR 6.0/2.9	+3.30	-5.08
Low fat	6.6	6.6	1.7YR 5.7/3.8	3.1YR 5.7/3.6	-3.27	-4.56
High fat	6.7	6.6	3.2YR 6.3/3.4	4.1YR 6.0/2.8	+4.21	-5.28
Low binding	6.7	6.6	1.8YR 5.5/3.5	3.0YR 5.9/3.6	-4.09	-3.45

^a4.7 oz./100 pounds of meat (25% Kurrol's salt + 75% tetrasodium-pyrophosphate)

^bUnits from Standard (3.5% NFDM bologna)

Tensile strength. An analysis of variance of tensile strength values was conducted and the results are presented in Table LII. Since the three-way interaction was significant when tested with the error term,

it became the new error term for testing all other interactions and treatments. It was established that significant differences existed between types of binders as well as between types of meat used. From previous comparisons it was anticipated that type of meat would have a significant influence upon the tensile strength of bologna.

Table LII. Analysis of variance of tensile strength of bologna from comparison III

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Binder-Tr.	3	6,581,163	2,193,721	22.06**
Meat-Tr.	3	5,923,240	1,974,413	19.91**
Replications	1	15,290	15,290	<1.0
Binder x Meat	9	2,304,879	256,098	2.58
Binder x Rep.	3	124,302	41,434	<1.0
Meat x Rep.	3	722,618	240,873	2.43
Binder x Meat x Rep.	9	892,899	99,211 ^b	13.74**
Error	288	2,079,580	7,221 ^a	
Total	319	18,643,971		

**Significant at 1% level

^aError term for three-way interaction

^bError term for all other interactions and treatments

The studentized range test (Table LIII) revealed that the phosphate treated bologna had significantly greater tensile strength than all other treatments, while the non-fat dry milk and soya grits treatments were significantly greater than the control but did not themselves differ. These findings are in agreement with the results reported by Swift and Ellis (1957). They reported increased tensile strength in bologna due to the addition of various phosphates. With respect to the type of meat used, it was established that the low fat (high lean) meat treatment had significantly greater tensile strength than all other types of meat tested. This is in agreement with the results of the second comparison and would

be expected since lean muscle tissue is the component generally considered to contribute most to the binding quality of sausage. It should be pointed out that the addition of low binding meat (pork hearts) equal to 50 percent of the pork trim reduced the tensile strength as much as the addition of pork containing 60 percent fat.

Table LIII. Tensile strength values of bologna from comparison III as influenced by various binders

Treatment	Means ranked	$\bar{X}$ -326.5	$\bar{X}$ -486.4	$\bar{X}$ -534.0
<u>Type of binder</u>				
Phosphate	728.6	402.1**	242.2**	194.6**
10% NFDM	534.0	207.5**	47.6	
10% Soya grits	486.4	159.9*		
Control	326.5			
Type of meat	Means ranked	$\bar{X}$ -426.5	$\bar{X}$ -429.0	$\bar{X}$ -467.2
Low fat	752.9	326.4**	323.9**	285.7**
Regular binding	467.2	40.7	38.2	
Low binding	429.0	2.5		
High fat	426.5			

*Significant at 5% level

**Significant at 1% level

Flavor preference. Results of an analysis of variance of flavor scores are presented in Table LIV. It was established that highly significant flavor differences were brought about by the addition of different binders and by employing different types of meat. It was also noted that significant differences existed between replications.

In Table LV it can be observed that the phosphate, non-fat dry milk, and control treatments were all scored significantly higher than the bologna treatment containing soya grits. This was expected since this level of soya grits was sufficient to influence considerably the color

Table LIV. Analysis of variance of flavor scores of bologna from comparison III

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Binder-Tr.	3	110.88	36.96	18.21**
Meat-Tr.	3	24.03	8.01	3.94**
Replications	1	11.40	11.40	5.62*
Binder x Meat	9	21.42	2.38	1.17
Binder x Rep.	3	5.09	1.70	<1.0
Meat x Rep.	3	4.90	1.63	<1.0
Binder x Meat x Rep.	9	19.75	2.19	1.08
Error	448	907.73	2.03	
Total	479	1,105.20		

*Significant at 5% level

**Significant at 1% level

of the product which may have introduced some bias, as well as yielding a product having a flavor that resembled the vegetable product it contained. While the differences were not significant, the mean values showed the phosphate and non-fat dry milk treatments were favored slightly over the control product. It should be noted here that only one level (ten percent) of soya grits was tested for comparison with the same level of non-fat dry milk. It is well known that many soya products contain materials that makes their application to sausage products self limiting. Gerrard (1955) stated that when soy-bean flour was used in small amounts, its flavor could be associated with that of beef. He suggested 2 1/2 percent soya flour for fresh sausage and slightly more for cooked sausage.

The low binding bologna formulation was scored significantly higher than the high and low fat formulations. Differences between the other treatments were not significant, however. While the fat content and/or the presence of pork hearts influenced the flavor considerably, it can be observed from Table L that values of 7.72 and 22.53 percent fat were

scored low on preference and bologna containing 12.89 percent fat with pork hearts or 20.44 percent fat (no hearts) were scored higher. From this it could be concluded that a fat content from 13 to 20 percent would result in a desirable product from the flavor aspect.

Table LV. Flavor scores of bologna from comparison III as influenced by various binders

Treatment	Mean		Means ranked	$\bar{X}$ -5.6	$\bar{X}$ -6.5	$\bar{X}$ -6.7
	Trial 1	Trial 2				
<u>Type of binder</u>						
Phosphate	7.1	6.6	6.8	1.2**	0.3	0.1
10% NFDM	6.8	6.6	6.7	1.1**	0.2	
Control	6.7	6.3	6.5	0.9**		
10% Soya grits	5.6	5.6	5.6			
<u>Type of meat</u>				$\bar{X}$ -6.2	$\bar{X}$ -6.4	
Low binding	7.0	6.4	6.7	0.5**	0.3	
Regular binding	6.6	6.3	6.4	0.2		
Low fat	6.4	6.0	6.2			
High fat	6.2	6.2	6.2			

**Significant at 1% level

Juiciness evaluation. The results of an analysis of the panel scores using a two-factor range test are given in Table LVI. A mean value of nine represents no difference from the standard, whereas values greater or less than nine represent greater or less juiciness, respectively, when compared with the standard which in this comparison was the control treatment. From Table LVI, it is clear that all treatments yielded bologna that was scored less juicy than the standard; however, ten percent soya grits was the only treatment that showed a significant difference from the standard, or control. According to Swift et al. (1954), additions of moisture or fat influenced noticeably the juiciness and tender-

ness of bologna, with moisture changes showing the greater effect. This agrees with the results reported here if one observes the mean values where type of meat was the variable. With increasing fat, there was increased juiciness even though this difference was not sufficient to show significance. This also agrees quite closely with the results reported in the second comparison.

Table LVI. Analysis of juiciness difference scores of bologna from comparison III using a two-factor range test

Treatment	Mean values	Sums ranked	Sum-830	Sum-911	Sum-1,029
<u>Type of binder</u>					
Control	9.1	1,088	258*	177	59
10% NFDM	8.6	1,029	199	118	
Phosphate	7.6	911	81		
10% Soya grits	6.9	830			
<u>Type of meat</u>					
			Sum-825	Sum-993	Sum-1,008
High fat	8.6	1,032	207 ^a	39	24
Regular binding	8.4	1,008	183	15	
Low binding	8.3	993	168		
Low fat	6.9	825			

*Significant at 5% level

^a208 required for significance at 5% level

Texture-Tenderness evaluation. From this analysis it was established that the addition of phosphate (4.7 oz. per 100 lb. of meat) significantly decreased the texture-tenderness when compared with the control. Soya grits or non-fat dry milk did not significantly increase or decrease the texture-tenderness when employed at the ten percent level (Table LVII). The mean values reveal that the addition of any one of these binders yielded bologna slightly tougher than the control and when compared with the tensile strength values of this comparison, they would

agree rather closely. The type of meat had a significant influence upon the texture-tenderness of the bologna somewhat more marked than could be established in the second comparison. The regular binding and high fat treatments were scored significantly more tender than the low fat treatment which, due to more lean tissue, would be expected to be somewhat tougher. Here again, agreement can be found with the results reported by Swift et al. (1954), who stated that variations in the fat content produced changes in tenderness of bologna. They found that increased fat produced increased tenderness in the product. In a later report, Swift and Ellis (1957) showed that the addition of various phosphates produced an increase in the tensile strength of bologna which would be related to the tenderness of the product. Dopner (1949), however, in reporting on the effects of phosphate in sausage products, stated that the type of meat and processing procedures would likely have greater effects on the binding of the product than would the addition of phosphates.

Table LVII. Analysis of texture-tenderness scores of bologna from comparison III using a two-factor range test

Treatment	Mean values	Sums ranked	Sum-701	Sum-842	Sum-905
<u>Type of binder</u>					
Control	8.7	1,042	341*	200	137
10% NFDM	7.5	905	204	63	
10% Soya grits	7.0	842	141		
Phosphate	5.8	701			
<u>Type of meat</u>					
Regular binding	8.0	966	254*	106	14
High fat	7.9	952	240*	92	
Low binding	7.1	860	148		
Low fat	5.9	712			

*Significant at 5% level

Investigation of the effects of non-fat dry milk, fermented non-fat dry milk, phosphates, and a starter culture on the processing and quality characteristics of bologna and thuringer, Comparison IV. This comparison was designed to compare the effects of non-fat dry milk and fermented non-fat dry milk in bologna and thuringer. Sodium tripolyphosphate was added in order to try to stabilize the emulsion, since preliminary studies with the fermented milk product indicated that emulsion breakdown had occurred during processing. It was intended to investigate and evaluate the possibility of using the fermented milk product in developing a new type sausage product. It is not commercial practice to add non-fat dry milk or other binders to semi-dry sausages, since these sausages are low in moisture content and binders would retard the removal of moisture from these products. In this investigation, however, it was believed that in new type products such binders might prove useful.

When analyzing the data, the results for bologna and thuringer were combined in order to better present the relationship that existed between the two products.

Percent yield. An analysis of variance was conducted and the results are presented in Table LVIII. From the analysis, it was found that treatment yields differed significantly. This difference in "out of cook" yield was expected, since both bologna and thuringer were analyzed together.

Table LVIII. Analysis of variance of percent yield of bologna and thuringer from comparison IV

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	7	1,726.20	246.00	32.54**
Replication	1	28.91	28.91	3.82
Tr. x Rep.	7	23.60	3.37	<1.0
Error	32	241.83	7.56	
Total	47	2,020.54		

**Significant at 1% level

On further analysis, it was established that the percent yield of thuringer was influenced considerably by the type of binder added. The mean percent yield of bologna, Table LIX, varied by approximately three percent, while the thuringer varied by as much as four percent between treatments. As expected, all bologna treatments showed significantly higher yields than the thuringer treatments. However, there were no significant differences between bologna treatments. These results are in agreement with those reported by Wilson (1954) who stated that no measurable increase in yield was obtained through the use of phosphates. As pointed out by Swift and Ellis (1956), the effectiveness of phosphates was believed dependent upon the processing variables, such as time and temperature, and this may explain the absence of significant differences between treatments due to the addition of phosphates. It was found with thuringer that non-fat dry milk gave significantly higher yields than the fermented non-fat dry milk treatments.

Heat treatment. The rate of heating was followed by using a recording potentiometer. The values observed were consistent between replications and, therefore, only values from the first trial are presented. It can be seen from Figure 4 (bologna) that the addition of 7.5 percent fermented non-fat dry milk had the greatest retarding effect on heat penetration. The addition of sodium tripolyphosphate also reduced the rate of heat transfer. The maximum temperature difference observed between treatments was approximately 15°F.

Due to maintenance of a constant temperature for an extended period during the early part of the heat process, only the last three hours were included for thuringer, Figure 5. It can be observed that the addition

Table LIX. Mean value of percent yield of bologna and thuringer from comparison IV

Treatment	Means ranked	$\bar{X}$ -79.85	$\bar{X}$ -82.08	$\bar{X}$ -84.10	$\bar{X}$ -84.35	$\bar{X}$ -92.26	$\bar{X}$ -94.48	$\bar{X}$ -94.92
<u>Bologna</u>								
3.5% NFDM	95.13	15.28**	13.05**	11.03**	10.78**	2.87	0.65	0.21
3.5% NFDM+P	94.92	15.07**	12.84**	10.82**	10.57**	2.66	0.44	
3.5% FNFDMP	94.48	14.63**	12.40**	10.38**	10.13**	2.22		
7.5% FNFDMP	92.26	12.41**	10.18**	8.16**	7.91**			
<u>Thuringer</u>								
3.5% NFDM+C	84.35	4.50*	2.27	0.25				
3.5% NFDM+C+P	84.10	4.25*	2.02					
3.5% FNFDMP	82.08	2.23						
3.5% FNFDMP	79.85							

*Significant at 5% level

**Significant at 1% level

C - Culture added (Pediococcus cerevisiae)

P - Sodium tripolyphosphate added

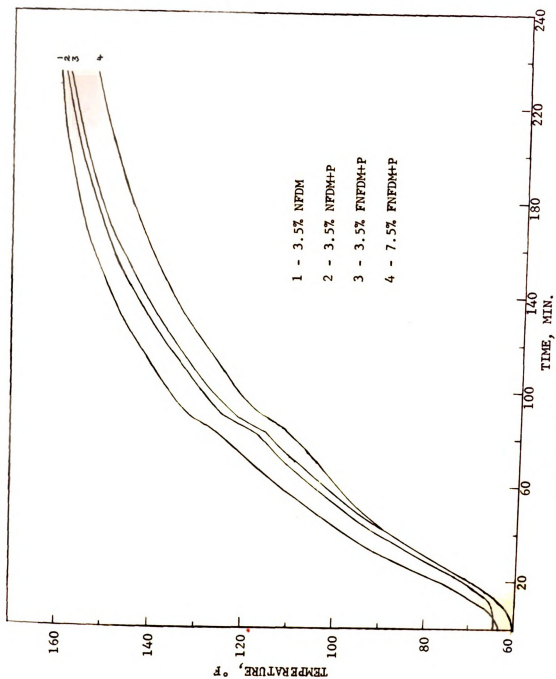


FIG. 4 RATE OF HEAT TRANSFER IN BOLOGNA

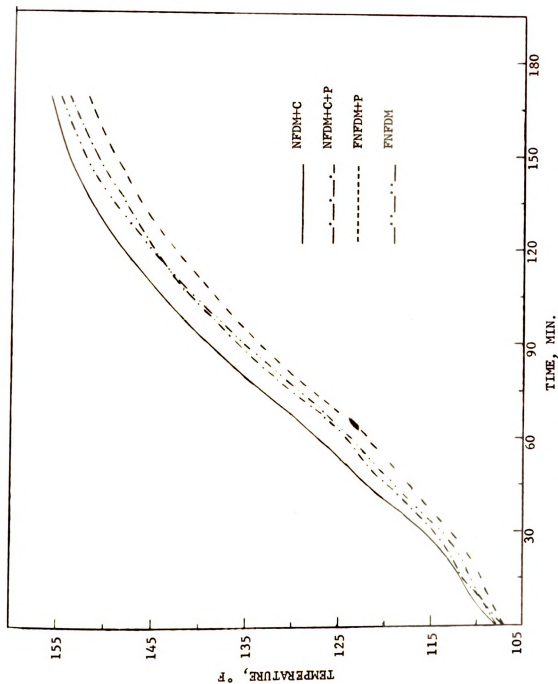


FIG. 5 RATE OF HEAT TRANSFER IN THURINGER

of fermented non-fat dry milk reduced the rate of heating over that of the non-fat dry milk treatment. As with bologna, the addition of phosphate in thuringer also reduced the rate of heat transfer.

With bologna and thuringer, the addition of fermented non-fat dry milk produced a more dense product than that containing non-fat dry milk and, therefore, heat transfer would be expected to be considerably reduced.

Percent shrinkage. Results from the analysis of variance (Table LX) indicated that treatments were significantly different. Here again, this was to be expected due to the combined analysis which included both bologna and thuringer.

Table LX. Analysis of variance of percent shrink (7 da.) of bologna and thuringer from comparison IV

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	7	48.87	6.98	36.74**
Replication	1	0.91	0.91	4.79
Tr. x Rep.	7	1.34	0.19	
Total	15	51.12		

**Significant at 1% level

On further analysis it became clear that the differences in shrinkage between treatments occurred primarily between the two products. There was a two to four percent greater shrinkage with bologna than thuringer due, for the most part, to the higher moisture content. It was observed, however, that differences between bologna treatments did not exist. The presence of fermented non-fat dry milk in thuringer with and without phosphate gave rise to significantly greater shrinkage than thuringer

Table LXI. Mean values of percent shrink (7 da.) of bologna and thuringer from comparison IV

Treatment	Means ranked	$\bar{X}$ -4.82	$\bar{X}$ -4.95	$\bar{X}$ -5.67	$\bar{X}$ -6.30	$\bar{X}$ -8.66	$\bar{X}$ -8.80	$\bar{X}$ -8.85
<u>Bologna</u>								
3.5% NFDM	8.98	4.16**	4.03**	3.31**	2.68**	0.32	0.18	0.13
7.5% NFDM+P	8.85	4.03**	3.90**	3.18**	2.55**	0.19	0.05	
3.5% NFDM+P	8.80	3.98**	3.85**	3.13**	2.50**	0.14.		
3.5% NFDM+P	8.66	3.84**	3.71**	2.99**	2.36**			
<u>Thuringer</u>								
3.5% NFDM	6.30	1.48*	1.35*	0.63				
3.5% NFDM+P	5.67	0.85	0.72					
3.5% NFDM+C	4.95	0.13						
3.5% NFDM+C+P	4.82							

*Significant at 5% level

**Significant at 1% level

C- Culture added (*Pediococcus cerevisiae*)

P -Sodium tripolyphosphate added

with non-fat dry milk plus phosphate. From the mean values, also presented in Table LXI, it is apparent that in all cases less shrinkage was observed where phosphate had been incorporated into the formulation. These differences were not all significant, however. It is interesting to note that while bologna contains more moisture than thuringer the mean values for percent yield indicated a greater yield for either product that contained non-fat dry milk, whereas the greatest percent shrinkage was observed for batches containing fermented non-fat dry milk within a given type of sausage.

Percent moisture. The results of the analysis of variance of percent moisture (Table LXII) did not show a significant difference between treatments even though the mean values ranged from 59.8 to 64.6 percent moisture (Appendix B, Table 4). This was somewhat surprising since the processing times varied considerably between the bologna and thuringer.

Table LXII. Analysis of variance of percent moisture of bologna and thuringer from comparison IV

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	7	29.0	4.14	2.88
Replication	1	6.9	6.90	4.79
Tr. x Rep.	7	10.1	1.44	
Total	15	46.0		

Percent protein. The results of this analysis of variance showed that significant differences existed between treatments as shown in Table LXIII.

Table LXIII. Analysis of variance of percent protein of bologna and thuringer from comparison IV

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	7	27.74	3.96	7.07**
Replication	1	1.24	1.24	2.21
Tr. x Rep.	7	3.91	0.56	
Total	15	32.89		

**Significant at 1% level

It was established on further analysis that the only treatments that differed significantly were thuringer, which contained 3.5 percent fermented non-fat dry milk, with and without added phosphate. Both of these treatments had significantly more protein than any of the bologna treatments. In addition, the 3.5 percent fermented non-fat dry milk thuringer treatment without phosphate differed from those batches of thuringer having 3.5 percent non-fat dry milk. These differences were attributed to the greater loss of moisture during cooking, which in effect concentrated the protein present in the product. Due to this inverse relationship, it can also be observed from the mean values presented in Table LXIV, that in all cases where phosphate was added, there existed a reduced protein content when compared with a similar treatment without phosphate. These means were not significantly different, even though this trend was apparent and consistent.

Percent fat. The results presented in Table LXV show that significant differences between treatments did not exist as determined by an analysis of variance. Large differences were not anticipated here since the fat content of the raw ingredients were approximately the same.

Table LXIV. Percent protein of bologna and thuringer from comparison IV as influenced by various binders

Treatment	Means						
	ranked	$\bar{X}$ -14.61	$\bar{X}$ -14.68	$\bar{X}$ -14.98	$\bar{X}$ -15.47	$\bar{X}$ -16.12	$\bar{X}$ -16.25 $\bar{X}$ -17.44
<u>Thuringer</u>							
3.5% FNFD	18.75	4.14**					
3.5% FNFD+P	17.44	2.83*	4.07**	3.77**	3.28**	2.63*	2.50* 1.31
3.5% NFDM+C	16.25	1.64	2.76*	2.46*	1.97*	1.32	1.19
3.5% NFDM+C+P	16.12	1.51	1.57	1.27	0.78	0.13	
			1.44	1.14	0.65		
<u>Bologna</u>							
7.5% FNFD+P	15.47	0.86	0.79	0.49			
3.5% NFDM	14.98	0.37	0.30				
3.5% FNFD+P	14.68	0.07					
3.5% NFDM+P	14.61						

*Significant at 5% level

**Significant at 1% level

C - Culture added (Pedococcus cerevisiae)

P - Sodium tripolyphosphate added

Table LXV. Analysis of variance of percent fat of bologna and thuringer from comparison IV

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	7	12.34	1.75	2.38
Replication	1	2.15	2.15	2.91
Tr. x Rep.	7	5.17	0.74	
Total	15	19.66		

pH determinations. The pH values are presented in Table LXVI for both trials of the fourth comparison. As was the case in earlier comparisons, the pH values were found to vary somewhat between replications. With bologna the pH was lowered considerably by the addition of the fermented milk product.

It was the desire of the author to produce thuringer having about equal tanginess (i.e. about the same pH values) by adding fermented non-fat dry milk and through the addition of a starter culture, Pediococcus cerevisiae. It is apparent from the pH values obtained, that 3.5 percent of the fermented non-fat dry milk produced pH values lower than through the use of the starter culture. The pH normally desired for this type of sausage commercially, ranges from 4.1 to 5.0; however, as will be shown later, the pH values obtained influenced markedly the flavor of the product.

Color evaluation. Also presented in Table LXVI are Color Renotation and Index of Fading Values for both trials. Due to the different formulation used for thuringer, the color was more of a red color, whereas the bologna was more toward the yellow-red as revealed by the renotation values. The positive and negative values for the Index of Fading Values indicate that the sample was either lighter (+) or darker (-) than the standard.

Table LXVI. pH, color renotation, and index of fading values of bologna and thuringer from comparison IV

Treatment	pH values		Color renotation		Index of fading ^c	
	Trial	Trial	Trial	Trial	Trial	Trial
	1	2	1	2	1	2
<u>Bologna</u>						
3.5% NFDM	6.1	6.4	1.6YR 6.1/3.5	1.7YR 5.8/3.3	+0.36	-2.20
3.5% NFDM+P ^a	6.1	6.4	1.5YR 6.0/3.7	1.7YR 6.0/3.2	-1.29	-1.90
3.5% FNFDM+P	5.7	6.0	1.5YR 6.0/3.6	1.8YR 6.2/3.1	-0.53	+2.47
7.5% FNFDM+P	5.4	5.7	1.6YR 6.2/3.5	2.0YR 6.0/3.0	+0.60	-2.42
<u>Thuringer</u>						
3.5% NFDM+C ^b	4.7	4.6	1.0YR 5.3/3.9	1.5YR 5.4/3.6	-6.52	-4.32
3.5% NFDM+C+P	5.1	4.9	1.2YR 5.5/3.5	1.0YR 5.9/3.7	-4.18	-2.52
3.5% FNFDM+P	4.6	4.6	1.8YR 5.5/3.7	1.8YR 5.7/3.3	-4.05	-3.36
3.5% FNFDM	4.3	4.3	1.0YR 5.5/3.8	1.7YR 5.8/3.4	-5.47	-2.41

^aSodium tripolyphosphate (6 oz./100 lb. of meat)

^bCulture added (*Pediococcus cerevisiae*, 1 oz./100 lb. of meat)

^cUnits from Standard (3.5% NFDM bologna)

Tensile strength. From an analysis of variance (Table LXVII) the results show that treatments differed significantly in tensile strength. It was also found that the treatment x replication interaction was significant which was the error term used for testing treatments and replications.

From the mean values for tensile strength presented in Table LXVIII, it can be seen that all treatments did not respond in the same way with respect to replication and this was believed the factor responsible for the significant interaction. It can also be observed from Table LXVIII that batches which received phosphate and low level (3.5 percent) non-fat dry milk or fermented non-fat dry milk had the greatest tensile strengths.

Table LXVII. Analysis of variance of tensile strength of bologna and thuringer from comparison IV

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	5	4,896,151	979,230	20.91**
Replication	1	10,830	10,830	<1.0
Tr. x Rep.	5	234,108	46,822 ^b	10.96**
Error	108	461,383	4,272 ^a	
Total	119	6,402,472		

**Significant at 1% level

^aError term for Tr. x Rep. interaction

^bError term for Treatments and Replications

Bologna, having a finer texture than thuringer, was expected to have a greater tensile strength and, with one exception, this was found to be true. The bologna treatments that contained 3.5 percent non-fat dry milk with phosphate and the 3.5 percent fermented non-fat dry milk with phosphate had significantly higher tensile strength values than bologna that contained 7.5 percent fermented non-fat dry milk or thuringer that contained 3.5 percent non-fat dry milk, with or without phosphate. The bologna treatment containing 3.5 percent non-fat dry milk had a significantly greater tensile strength than the bologna with 7.5 percent fermented non-fat dry milk plus phosphate and 3.5 percent non-fat dry milk thuringer treatment. It should be noted that thuringer that contained 3.5 percent fermented non-fat dry milk, with or without phosphate, was too brittle for tensile strength evaluation. These findings are in accord with the results reported by Swift and Ellis (1957) wherein phosphates were found to increase the tensile strength of bologna. The differences reported here show the same trend but were not as great as those reported by the above mentioned authors.

Table LXVIII. Tensile strength values of bologna and thuringer from comparison IV as influenced by various binders

Treatment	Means ranked	$\bar{X}$ -218	$\bar{X}$ -347	$\bar{X}$ -484	$\bar{X}$ -655	$\bar{X}$ -718
<u>Bologna</u>						
3.5% NFDM+P	778	560**	431**	294*	123	60
3.5% FNFDMP	718	500**	371**	234*	63	
3.5% NFDM	655	437**	308**	171		
<u>Thuringer</u>						
3.5% NFDM+C+P	484	266*	137			
3.5% NFDM+C	347	129				
<u>Bologna</u>						
7.5% FNFDMP	218					

*Significant at 5% level

**Significant at 1% level

Note: Thuringer with 3.5% FNFDMP with and without phosphate was too brittle to test.

Flavor evaluation. Results of the analysis of variance of flavor scores are presented in Table LXIX. It was found that treatment caused significant differences in flavor preference as evaluated by the taste panel. In addition, it was noted that the treatment x replication interaction differed significantly when tested with the error term and therefore this interaction was used in testing treatments for differences.

Table LXIX. Analysis of variance of flavor preference scores of bologna and thuringer from comparison IV

Source of variance	Degrees of freedom	Sum of squares	Mean square	F-value
Treatment	7	389.4	55.63	10.57**
Replication	1	4.0	4.00	<1.0
Tr. x Rep.	7	36.8	5.26 ^b	2.32*
Error	224	509.8	2.27 ^a	
Total	239	940.0		

**Significant at 1% level

*Significant at 5% level

^aError term for Tr. x Rep. interaction

^bError term for Treatments and Replications

Further analysis, presented in Table LXX, showed that bologna with 3.5 percent non-fat dry milk (control) received a significantly higher flavor preference score than all thuringer treatments as well as the bologna treatment which contained 7.5 percent of the fermented non-fat dry milk plus phosphate. The bologna treatments with phosphate plus 3.5 percent non-fat dry milk or fermented non-fat dry milk were both scored significantly higher than bologna with 7.5 percent fermented non-fat dry milk and phosphate or thuringer with 3.5 percent non-fat dry milk, or 3.5 percent fermented non-fat dry milk with or without phosphate. All treatments of bologna and thuringer were scored significantly higher than the thuringer treatments which contained 3.5 percent fermented non-fat dry milk with or without phosphate. In general, this analysis showed that in bologna which contained 3.5 percent fermented non-fat dry milk there might be some promise of producing a bologna type sausage product with a desirable tangy flavor.

Juiciness evaluation. The results of a one-factor range test for analyzing juiciness difference scores are presented in Table LXXI. A value of nine represented no difference from the test standard, which for bologna was the 3.5 percent non-fat dry milk treatment. The analysis revealed that none of the bologna treatments differed significantly from the standard, although based on total difference, it was found that 7.5 percent fermented non-fat dry milk plus phosphate yielded significantly juicier bologna than 3.5% non-fat dry milk plus phosphate. With thuringer it can be observed that treatments which contained fermented non-fat dry milk were juicier than those which contained non-fat dry milk plus phosphate. Here again, however, there were no significant differences

Table LXX. Flavor preference of bologna and thuringer from comparison IV as influenced by NFDM and phosphate combinations

Treatment	Mean		Means of		$\bar{X}$ -3.7	$\bar{X}$ -4.4	$\bar{X}$ -5.4	$\bar{X}$ -5.7	$\bar{X}$ -6.3	$\bar{X}$ -7.0	$\bar{X}$ -7.2
	Trial 1	Trial 2	Trial 1	Trial 2							
B ^a -3.5% NFDM	7.3	7.5	7.4	7.4	3.7**	3.0**	2.0**	1.7**	1.1*	0.4	0.2
B-3.5% FNFDMP	7.2	7.2	7.2	7.2	3.5**	2.8**	1.8**	1.5**	0.9	0.2	
B-3.5% NFDM+P	6.9	7.1	7.0	7.0	3.3**	2.6**	1.6**	1.3*	0.7		
T ^b -3.5% NFDM+C+P	7.1	5.5	6.3	6.3	2.6**	1.9**	0.9	0.6			
B-7.5% FNFDMP	5.7	5.7	5.7	5.7	2.0**	1.3*	0.3				
T-3.5% NFDM+C	6.3	4.6	5.4	5.4	1.7**	1.0*					
T-3.5% FNFDMP	4.3	4.5	4.4	4.4	0.7						
T-3.5% FNFDMP	3.5	3.9	3.7	3.7							

*Significant at 5% level

**Significant at 1% level

^aBologna

^bThuringer

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from the thuringer standard which contained 3.5 percent non-fat dry milk plus culture.

In general, the addition of the fermented product increased juiciness of bologna and thuringer. It could also be assumed that the addition of phosphate presented a product with an apparent, if not real, reduction in juiciness.

Table LXXI. Analysis of juiciness differences of bologna and thuringer from comparison IV using a one-factor range test

Treatment	Mean value	Sums ranked	Sum-16.1	Sum-17.7	Sum-19.5
<u>Bologna</u>					
7.5% FNFDMP	10.0	20.0	3.9*	2.3	0.5
3.5% FNFDMP	9.8	19.5	3.4	1.8	
3.5% NFDM	8.8	17.7	1.5		
3.5% NFDM+P	8.0	16.1			
			Sum-15.8	Sum-17.5	Sum-18.9
<u>Thuringer</u>					
3.5% FNFDMP	9.6	19.1	3.3*	2.6	0.2
3.5% FNFDMP	9.4	18.9	3.1*	1.4	
3.5% NFDM+C	8.8	17.5	1.7		
3.5% NFDM+C+P	7.9	15.8			

*Significant at 5% level

Texture-tenderness evaluation. The results of an analysis of the panel scores are presented in Table LXXII. The 3.5 percent non-fat dry milk was used as the bologna standard, whereas for thuringer, the standard contained 3.5 percent non-fat dry milk plus a starter culture. A mean value of nine represented no difference and values greater or less than nine indicated that the treatment was judged more or less tender than the standard, respectively, where the texture of the product was taken into account.

It was established that 7.5 percent fermented non-fat dry milk plus phosphate was scored as being significantly more tender than bologna containing 3.5 percent non-fat dry milk. Through preliminary tests with the fermented milk product, it was found that the texture was markedly influenced. The bologna possessed a very dense texture and was quite soft and mushy, comparable to that of potted meat. It was believed that the addition of phosphate would reduce this effect. This was found to be the case where low levels were employed, as revealed by the results which indicated no significant differences between fermented plus phosphate and non-fermented milk treatments.

With respect to variations in thuringer under similar tests, it was established that significant differences in texture-tenderness were not present. Here again, however, the mean values show that a more tender product was produced where fermented non-fat dry milk was employed. The addition of phosphate was responsible for a slight improvement (toughening) of the product when considering the standard as having a desirable degree of texture-tenderness.

Table LXCLI. Differences in texture-tenderness scores of bologna and thuringer from comparison IV as determined with a one-factor range test

Treatment	Mean value	Sums ranked	Sum-15.2	Sum-18.5	Sum-18.9
<u>Bologna</u>					
7.5% FNFDMP	12.0	23.9	8.7*	5.4	5.0
3.5% FNFDMP	9.4	18.9	3.7	0.4	
3.5% NFDM	9.2	18.5	3.3		
3.5% NFDM+P	7.6	15.2			
			Sum-16.3	Sum-18.1	Sum-22.0
<u>Thuringer</u>					
3.5% FNFDMP	11.8	23.5	7.2 ^a	5.4	1.5
3.5% FNFDMP	11.0	22.0	5.7	3.9	
3.5% NFDM+C	9.0	18.1	1.8		
3.5% NFDM+C+P	8.2	16.3			

*Significant at 5% level

^a7.3 required for significance at 5% level

SUMMARY AND CONCLUSIONS

The objectives of this investigation were to establish the effects of non-fat dry milk, phosphates, soya grits, fermented non-fat dry milk, and types of meat on the binding qualities of bologna type sausage. These were accomplished by conducting a series of comparison tests. Processing and quality characteristics were evaluated in order to establish the effectiveness. The first comparison was a study of the effectiveness of various levels of non-fat dry milk in bologna. The second comparison included two levels of non-fat dry milk and four types of meat having different binding qualities. After establishing a satisfactory level of non-fat dry milk, a comparison of non-fat dry milk with a phosphate mixture (25% crossed-linked potassium Kurrol's salt and 75% tetrasodiumpyrophosphate) and soya grits was carried out, again testing the four types of meat. The fourth comparison was directed toward the utilization of fermented non-fat dry milk in bologna and thuringer.

It was concluded from the first comparison that the addition of 3.5 percent non-fat dry milk increased the yield of bologna significantly over that of the control or 20 percent non-fat dry milk treatment. The shrinkage over a seven day period was not affected by the addition of non-fat dry milk.

Chemical analysis of the bologna showed no difference in either percent moisture or protein when 3.5, 10, 15 or 20 percent non-fat dry milk was added. Differences were noted in the percent fat, but this effect was due to the non-fat dry milk that was substituted for meat in the formulation.

The pH of the finished product was increased approximately 0.1 pH unit by the addition of non-fat dry milk. With increased levels of non-fat dry milk, the color of the bologna became lighter, due primarily to dilution of the meat pigment concentration and whiteness of the milk.

Tensile strength of bologna was increased with 3.5, 10, and 15 percent non-fat dry milk, with the 3.5 and ten percent levels showing the greatest effect. The 3.5 and ten percent treatments contributed more to flavor than any of the other treatments, while ten and 20 percent non-fat dry milk increased juiciness to the greatest extent. Texture-tenderness differences were scored greater with increased levels of non-fat dry milk.

In the second comparison, both the 3.5 and ten percent non-fat dry milk treatments produced greater yield values over the control. With variations in the type of meat used, it was concluded that the high fat, regular, and low binding formulations gave a greater yield than did the low fat formulation. The percent shrinkage over a seven day period was not affected by any of the treatments employed.

As in the first comparison, non-fat dry milk did not have a significant influence on the moisture or protein content at the levels tested. The meat treatments did have a significant influence upon both the moisture and protein content of the bologna. Moisture and protein were found to vary inversely with the fat content of the finished product. The percent fat was influenced significantly by both non-fat dry milk and the type of meat.

pH and color effects were slight in this comparison, producing only about 0.2 pH units difference between treatments and with non-fat dry milk

yielding higher values. The color was not lightened to any extent at the ten percent level of non-fat dry milk.

As in the first comparison, tensile strength was greater where non-fat dry milk was employed. All types of meat tested had greater tensile strength than the low binding meat formulation.

Neither the flavor nor texture-tenderness of bologna were influenced significantly with the treatments tested in this comparison. However, the control was significantly more juicy than the 3.5 percent non-fat dry milk treatment. The low fat formulation was less juicy than all other meat treatments.

In the third comparison, it was established that the addition of phosphate (4.7 oz./100 lb. meat of a mixture containing 25 percent cross-linked potassium Kurrol's salt and 75 percent tetrasodiumpyrophosphate) produced a significant increase in yield over the control. Differences were not established between the phosphate and ten percent of either soya grits or non-fat dry milk. The regular binding and high fat formulations produced greater yields than did low binding or low fat formulations.

It was further established that shrinkage over a seven day period was significantly greater with phosphate or soya grits than with non-fat dry milk. The type of meat did not influence shrinkage during storage. The soya grits treatment contained less moisture in the finished product than all other treatments. The low fat and low binding formulations contained more moisture than the regular binding or high fat treatments.

The protein content of the finished product was higher with soya grits than with any other binder tested, but this was due primarily to the much lower moisture content. The low fat treatment yielded a higher protein content than all other meat treatments. The fat content was

significantly lower in the presence of non-fat dry milk or soya grits, due to substitution for meat. The types of meat used had a significant influence upon the fat content of bologna.

The type of meat produced only slight effects on pH of the finished product, whereas the addition of non-fat dry milk, soya grits, and phosphate increased the pH of bologna by 0.1 to 0.4, with soya grits and phosphate having the greatest effect. The color of bologna was influenced by the type of meat used in that a higher fat content yielded a lighter color and pork hearts or low fat yielded a redder color. The addition of soya grits resulted in more yellow color while phosphate and non-fat dry milk produced only slight changes in color.

The addition of phosphate, non-fat dry milk, or soya grits significantly increased the tensile strength, with phosphate having the greatest influence. The low fat formulation had a greater tensile strength than any other meat formulations.

It was concluded that the phosphate, non-fat dry milk, or control treatment had a more desirable flavor than the soya grits treatment. The low binding formulation yielded a more desirable flavor than that having a high fat content. The addition of soya grits significantly decreased the juiciness as compared to the control while the addition of phosphate, non-fat dry milk or type of meat failed to produce significant juiciness differences. It was established that the addition of phosphate yielded lower texture-tenderness values compared with the control as did the low fat meat treatment when compared with the regular binding and high fat treatments.

In the fourth comparison it was established that in thuringer, the addition of non-fat dry milk, with or without sodium tripolyphosphate,

resulted in significantly greater yields than the addition of fermented non-fat dry milk. It was further noted that non-fat dry milk alone yielded approximately 0.25 percent more out of cook than the combination of non-fat dry milk and sodium tripolyphosphate.

The presence of fermented non-fat dry milk in thuringer resulted in significantly greater shrinkage than thuringer containing non-fat dry milk with or without phosphate. The percent moisture in bologna and thuringer was not influenced by the treatments employed in this comparison. Thuringer with fermented non-fat dry milk contained significantly more protein than that containing non-fat dry milk with or without phosphate. The fat content was not influenced significantly by the variables of this comparison.

The addition of fermented non-fat dry milk or non-fat dry milk plus starter culture resulted in decreased pH values in the finished product. Color differences were only slight when non-fat dry milk and fermented non-fat dry milk were compared in thuringer or bologna.

The addition of 7.5 percent fermented non-fat dry milk significantly reduced the tensile strength of bologna when compared with 3.5 percent fermented or plain non-fat dry milk plus phosphate.

Flavor preference was significantly lower for bologna containing 7.5 percent fermented non-fat dry milk than all other bologna treatments. With thuringer, the flavor was less desirable where fermented non-fat dry milk was used in comparison to non-fat dry milk plus culture. This difference was due to the lower pH of the fermented product. Juiciness of bologna was increased significantly by the addition of 7.5 percent fermented non-fat dry milk when compared with bologna containing 3.5 percent

non-fat dry milk plus phosphate. With thuringer, 3.5 percent of the fermented milk product increased juiciness over that of the same level of non-fat dry milk with or without phosphate. It was established that bologna with 7.5 percent fermented non-fat dry milk plus phosphate was significantly more tender than bologna containing 3.5 percent non-fat dry milk plus phosphate. In general, the addition of fermented non-fat dry milk yielded greater tenderness in either bologna or thuringer.

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Appendix A

Table 1. Formulations* of bologna, comparison I

Batch formulation	Control	Percent non-fat dry milk			
		3.5	10	15	20
Pork	10.0	9.15	7.7	6.5	5.2
Beef	10.0	9.15	7.7	6.5	5.2
Ice	5.0	5.85	7.3	8.5	9.8
NFDM		0.85	2.3	3.5	4.8
Spice	45.4	43.5	40.2	37.5	34.5
Sugar	56.7	32.6			
Salt	136.0	130.3	120.4	112.2	103.4
Nitrite	1.4	1.4	1.4	1.4	1.4
Nitrate	1.4	1.4	1.4	1.4	1.4
Ascorbate	4.0	4.0	4.0	4.0	4.0

*Beef, pork, ice, and NFDM in pounds, balance in grams.

Table 2. Formulations* of bologna, comparison II

Batch formulation	Control				3.5% NFDM				10.0% NFDM			
	reg. bind	low fat	high fat	low bind	reg. bind	low fat	high fat	low bind	reg. bind	low fat	high fat	low bind
Beef	10.0	10.0	10.0	10.0	9.15	9.15	9.15	9.15	7.7	7.7	7.7	7.7
Pork trim												
50% lean	10.0	---	---	5.0	9.15	---	---	4.6	7.7	---	---	3.9
90% lean	---	10.0	---	---	---	9.15	---	---	---	7.7	---	---
40% lean	---	---	10.0	---	---	---	9.15	---	---	---	7.7	---
Pork hearts	---	---	---	5.0	---	---	---	4.6	---	---	---	3.9
Ice	5.0	5.0	5.0	5.0	5.85	5.85	5.85	5.85	7.3	7.3	7.3	7.3
NFDM	---	---	---	---	0.85	0.85	0.85	0.85	2.3	2.3	2.3	2.3
Seasoning	45.4	45.4	45.4	45.4	43.5	43.5	43.5	43.5	40.2	40.2	40.2	40.2
Sugar	56.7	56.7	56.7	56.7	32.6	32.6	32.6	32.6	---	---	---	---
Salt	136.0	136.0	136.0	136.0	130.3	130.3	130.3	130.3	120.4	120.4	120.4	120.4
Nitrite	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Nitrate	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Ascorbate	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

*Beef, pork, ice and NFDM in pounds, balance in grams.

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Table 3. Formulations* of bologna, comparison III

Batch formulation	Control				10% NFDM			
	reg. bind	low fat	high fat	low bind	reg. bind	low fat	high fat	low bind
Beef	10.0	10.0	10.0	10.0	7.7	7.7	7.7	7.7
Pork								
50% lean	10.0	--	--	5.0	7.7	--	--	3.9
90% lean	--	10.0	--	--	--	7.7	--	--
40% lean	--	--	10.0	--	--	--	7.7	--
Pork hearts	--	--	--	5.0	--	--	--	3.9
Ice	5.0	5.0	5.0	5.0	7.3	7.3	7.3	7.3
NFDM	--	--	--	--	2.3	2.3	2.3	2.3
Soya grits	--	--	--	--	--	--	--	--
Phosphate	--	--	--	--	--	--	--	--
Seasoning	45.4	45.4	45.4	45.4	40.2	40.2	40.2	40.2
Sugar	56.7	56.7	56.7	56.7	--	--	--	--
Salt	136.0	136.0	136.0	136.0	120.4	120.4	120.4	120.4
Nitrite	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Nitrate	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Ascorbate	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

*Beef, pork, ice and NFDM in pounds, balance in grams.

Table 3. Formulations* of bologna, comparison III (continued)

Batch formulation	10% Soya grits				Phosphate			
	reg. bind	low fat	high fat	low bind	reg. bind	low fat	high fat	low bind
Beef	7.7	7.7	7.7	7.7	10.0	10.0	10.0	10.0
Pork								
50% lean	7.7	--	--	3.9	10.0	--	--	5.0
90% lean	--	7.7	--	--	--	10.0	--	--
40% lean	--	--	7.7	--	--	--	10.0	--
Pork hearts	--	--	--	3.9	--	--	--	5.0
Ice	7.3	7.3	7.3	7.3	5.0	5.0	5.0	5.0
NFDM	--	--	--	--	--	--	--	--
Soya grits	2.3	2.3	2.3	2.3	--	--	--	--
Phosphate	--	--	--	--	26.7	26.7	26.7	26.7
Seasoning	40.2	40.2	40.2	40.2	45.4	45.4	45.4	45.4
Sugar	43.7	43.7	43.7	43.7	56.7	56.7	56.7	56.7
Salt	120.4	120.4	120.4	120.4	136.0	136.0	136.0	136.0
Nitrite	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Nitrate	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Ascorbate	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

*Beef, pork, ice and NFDM in pounds, balance in grams.

Table 4. Formulations* of bologna and thuringer, comparison IV

Batch formulation	Bologna				Thuringer			
	3.5% NFDM	3.5% NFDM+P	3.5% FNFDMP	7.5% FNFDMP	3.5% NFDM+C	3.5% NFDM+G+P	3.5% FNFDMP	3.5% FNFDMP
Beef	9.15	9.15	9.15	8.2	11.0	11.0	11.0	11.0
Pork	9.15	9.15	9.15	8.2	7.3	7.3	7.3	7.3
Ice	5.85	5.85	5.85	6.8	5.85	5.85	5.85	5.85
NFDM	0.85	0.85	0.85	1.8	0.85	0.85	--	--
FNFDMP	--	--	--	--	--	--	0.85	0.85
Phosphate (sodium tripoly-)	--	31.2	31.2	31.2	--	31.2	31.2	--
Culture	--	--	--	--	6.0	6.0	--	--
Spices	43.5	43.5	43.5	41.5	43.5	43.5	43.5	43.5
Sugar	33.0	33.0	33.0	33.0	33.0	33.0	33.0	33.0
Salt	130.0	130.0	130.0	124.0	130.0	130.0	130.0	130.0
Nitrite	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Nitrate	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Ascorbate	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

*Beef, pork, ice, NFDM, and FNFDMP in pounds, balance in grams.

Table 5. Formulation of spice mixture

Dried soluble seasoning on a salt base*

4 oz. black pepper

2 oz. coriander

1 oz. mace

1/2 oz. ginger

1/4 oz. allspice

*One pound of salt base seasoning is equivalent to one pound of salt.

Calculations were based on a two percent salt requirement for bologna based on weight of meat and non-fat dry milk, or eight ounces of spices plus 24 ounces of salt per 100 pounds of meat.

Appendix B

Table 1. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna from comparison I

Factor evaluated	Trial No.	Control	Percent non-fat dry milk			
			3.5	10	15	20
% Yield	1	89.83	91.23	90.77	90.35	89.44
	2	92.13	94.42	93.54	93.68	92.86
% Shrink	1	8.04	7.20	8.30	7.69	6.29
	2	9.43	8.03	7.87	7.73	7.55
% Moisture	1	53.72	56.46	56.31	56.03	56.87
	2	60.68	61.57	61.70	62.41	62.38
% Protein	1	12.86	13.10	13.53	13.41	14.32
	2	13.78	13.50	13.76	14.41	14.38
% Fat	1	30.53	25.84	22.64	19.48	15.30
	2	22.86	20.76	17.43	12.66	9.95
pH values	1	6.10	6.20	6.20	6.25	6.25
	2	6.15	6.30	6.30	6.30	6.45
Color values	1	1.3YR 6.3/2.7	1.6YR 6.3/2.8	3.7YR 6.3/2.6	2.7YR 6.3/3.1	3.6YR 6.3/2.8
	2	.95YR 6.3/3.4	2.3YR 6.3/3.0	2.7YR 6.3/3.2	3.1YR 6.3/3.0	3.7YR 6.3/2.7
Tensile strength	1	272 ^a	430	513	363	224
	2	366	685	504	479	171
Flavor preference	1	6.5	7.7	7.3	6.8	5.3
	2	6.7	7.4	7.3	6.6	5.7
Juiciness difference	1 ^b					
	2	1.6 ^c	2.6	3.5	2.8	3.4

Table 1. Mean values for yield, shrink, moisture, proteolysis, fat, pH, color retention, tensile strength, flavor, juiciness, and texture-tenderness of bologna from comparison I (continued)

Factor evaluated	Trial No.	Control	Percent non-fat dry milk		
			3.5	10	15
Texture-tenderness difference	1	3.5	1.1 ^d	2.5	4.0
	2	2.5	3.3 ^d	4.0	3.7

5.2
6.0

^aGrams

^bIncluded with trial 1, texture-tenderness

^cStandard

^dStandard

Table 2. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna from comparison II

	Control			
	Reg. bind	Low fat	High fat	Low bind
% Yield				
Trial 1	94.43	92.15	95.38	93.02
Trial 2	92.62	91.15	92.22	92.39
% Shrink				
Trial 1	10.85	10.81	9.79	9.91
Trial 2	11.07	10.82	10.11	11.10
% Moisture				
Trial 1	64.14	73.09	59.34	68.71
Trial 2	62.02	71.31	59.09	68.80
% Protein				
Trial 1	14.69	18.03	13.44	15.88
Trial 2	14.56	18.35	14.02	15.44
% Fat				
Trial 1	18.29	7.57	24.20	12.23
Trial 2	20.32	7.20	23.87	12.66
pH values				
Trial 1	6.3	6.3	6.4	6.5
Trial 2	6.2	6.3	6.4	6.5
Color values				
Trial 1	1.7YR 6.3/3.8	1.0YR 6.4/4.5	1.5YR 6.3/3.4	1.0YR 6.3/4.2
Trial 2	2.9YR 6.4/3.6	1.3YR 6.3/3.9	2.3YR 6.3/3.6	1.1YR 6.3/4.2
Tensile strength				
Trial 1	437	532	410	326
Trial 2	378	400	411	352
Flavor preference				
Trial 1	6.9	7.0	6.9	7.1
Trial 2	6.9	6.9	7.2	7.5
Juiciness difference				
Trial 1	9.8 ^a	5.8	10.4	8.9
Trial 2	9.0 ^a	7.7	9.9	9.4
Texture-tenderness difference				
Trial 1	8.9 ^b	7.8	9.2	8.9
Trial 2	8.9 ^b	7.3	9.5	9.5

^aStandard
^bStandard

Table 2. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna from comparison II (continued)

	3.5% DMS			
	Reg. bind	Low fat	High fat	Low bind
% Yield				
Trial 1	95.18	92.78	95.22	94.19
Trial 2	94.10	91.82	94.29	93.24
% Shrink				
Trial 1	10.09	10.07	9.44	10.04
Trial 2	10.54	9.87	10.41	10.55
% Moisture				
Trial 1	64.49	71.64	59.48	68.97
Trial 2	63.32	70.88	61.27	67.88
% Protein				
Trial 1	14.94	18.50	13.66	16.18
Trial 2	14.62	17.94	14.22	15.22
% Fat				
Trial 1	16.00	5.11	22.53	10.64
Trial 2	17.34	6.34	20.20	12.41
pH values				
Trial 1	6.6	6.6	6.3	6.3
Trial 2	6.4	6.4	6.4	6.4
Color values				
Trial 1	1.7YR 6.4/4.0	.83YR 6.3/4.4	1.6YR 6.3/3.6	1.3YR 6.4/4.4
Trial 2	2.4YR 6.3/3.5	1.3YR 6.3/4.1	2.5YR 6.3/3.5	1.2YR 6.3/4.2
Tensile strength				
Trial 1	747	811	768	631
Trial 2	510	891	626	576
Flavor preference				
Trial 1	6.7	6.5	7.1	6.8
Trial 2	7.2	6.9	7.7	7.0
Juiciness difference				
Trial 1	8.4	6.7	8.9	7.5
Trial 2	7.6	5.4	8.7	9.6
Texture-tenderness difference				
Trial 1	7.8	6.7	10.1	9.2
Trial 2	8.1	5.2	--	9.2

1. The first part of the document is a list of the names of the members of the committee.

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Table 2. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna from comparison II (continued)

	10.0% DMS			
	Reg. bind	Low fat	High fat	Low bind
% Yield				
Trial 1	94.53	92.68	95.51	93.38
Trial 2	93.92	91.54	94.24	92.84
% Shrink				
Trial 1	9.66	10.58	9.80	10.23
Trial 2	9.90	10.34	9.97	10.42
% Moisture				
Trial 1	63.64	70.40	60.18	67.94
Trial 2	62.58	68.98	61.31	67.62
% Protein				
Trial 1	15.34	17.66	13.97	16.81
Trial 2	14.53	17.56	14.27	15.91
% Fat				
Trial 1	13.18	3.96	18.29	8.29
Trial 2	15.25	5.08	16.88	9.36
pH values				
Trial 1	6.35	6.35	6.35	6.3
Trial 2	6.35	6.35	6.3	6.3
Color values				
Trial 1	1.9YR 6.3/3.8	1.2YR 6.4/4.8	1.7YR 6.3/3.7	1.0YR 6.3/4.2
Trial 2	2.5YR 6.4/3.7	1.3YR 6.3/3.9	2.5YR 6.3/3.3	1.2YR 6.3/4.3
Tensile strength				
Trial 1	461	957	504	534
Trial 2	591	854	555	635
Flavor preference				
Trial 1	6.9	6.4	7.1	6.7
Trial 2	6.8	6.8	6.5	7.0
Juiciness difference				
Trial 1	9.3	5.9	9.3	7.3
Trial 2	9.6	6.4	9.9	9.0
Texture-tenderness difference				
Trial 1	8.4	7.0	9.3	8.0
Trial 2	9.9	7.0	9.7	8.7

Table 3. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna from comparison III

Batch #	Control			
	Reg. bind 1	Low fat 2	High fat 3	Low bind 4
% Yield				
Trial 1	95.18	92.94	93.21	93.21
Trial 2	93.53	91.58	93.99	92.41
% Shrink				
Trial 1	7.82	8.80	7.92	7.78
Trial 2	8.08	9.17	8.84	8.79
% Moisture				
Trial 1	59.91	70.93	58.18	66.82
Trial 2	58.14	69.29	57.65	66.01
% Protein				
Trial 1	13.82	16.91	13.06	15.10
Trial 2	13.88	18.22	13.34	15.97
% Fat				
Trial 1	23.17	8.90	25.44	14.63
Trial 2	24.92	9.48	26.05	15.46
pH values				
Trial 1	6.40	6.45	6.40	6.45
Trial 2	6.40	6.30	6.40	6.45
Color values				
Trial 1	2.0YR 6.4/3.3	1.8YR 6.0/3.7	2.0YR 6.6/3.2	1.5YR 5.8/3.8
Trial 2	3.2YR 6.2/3.2	2.5YR 5.9/3.6	2.8YR 5.9/3.2	2.6YR 5.7/3.5
Tensile strength				
Trial 1	406	404	278	260
Trial 2	350	388	265	262
Flavor preference				
Trial 1	6.8	6.6	6.5	6.9
Trial 2	6.5	5.7	6.4	6.7
Juiciness difference				
Trial 1	9.9 ^a	8.3	7.8	8.8
Trial 2	9.8 ^a	9.4	9.9	9.6
Texture-tenderness difference				
Trial 1	8.9 ^b	9.2	8.6	8.0
Trial 2	9.0 ^b	7.9	8.7	9.2

^aStandard

^bStandard

Table 3. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna from comparison III (continued)

Batch #	10% NFDM			
	Reg. bind 5	Low fat 6	High fat 7	Low bind 8
% Yield				
Trial 1	94.86	92.91	95.01	93.64
Trial 2	94.51	92.63	93.51	92.63
% Shrink				
Trial 1	7.34	7.72	7.60	7.59
Trial 2	7.82	8.98	7.83	8.40
% Moisture				
Trial 1	61.66	69.10	60.28	67.34
Trial 2	60.06	68.78	59.42	65.52
% Protein				
Trial 1	13.90	16.69	13.62	15.16
Trial 2	14.50	17.25	13.69	15.78
% Fat				
Trial 1	16.83	6.02	18.66	9.88
Trial 2	18.48	6.44	19.25	11.58
pH values				
Trial 1	6.50	6.50	6.55	6.55
Trial 2	6.40	6.40	6.50	6.50
Color values				
Trial 1	3.2YR 5.9/3.0	1.7YR 5.9/3.5	2.9YR 6.4/3.2	1.7YR 5.8/3.7
Trial 2	3.2YR 5.9/2.8	2.5YR 5.9/3.4	3.0YR 5.8/2.9	3.2YR 5.9/3.5
Tensile strength				
Trial 1	436	792	406	398
Trial 2	439	789	505	507
Flavor preference				
Trial 1	6.5	6.4	6.9	7.3
Trial 2	6.7	6.5	6.7	6.3
Juiciness difference				
Trial 1	9.4	6.5	8.9	9.0
Trial 2	9.7	7.1	8.7	9.1
Texture-tenderness difference				
Trial 1	7.4	7.7	7.9	--
Trial 2	5.7	7.4	7.8	--

Table 3. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna from comparison III (continued)

Batch #	10% Soya grits			
	Reg. bind 9	Low fat 10	High fat 11	Low bind 12
% Yield				
Trial 1	94.91	93.23	93.84	93.56
Trial 2	94.48	92.66	94.57	93.13
% Shrink				
Trial 1	8.15	8.43	8.41	8.80
Trial 2	8.56	9.54	8.68	9.42
% Moisture				
Trial 1	60.23	67.26	57.88	64.92
Trial 2	58.49	67.22	57.49	64.40
% Protein				
Trial 1	15.85	18.72	15.70	17.41
Trial 2	16.00	19.88	15.44	17.47
% Fat				
Trial 1	16.60	6.66	19.22	10.70
Trial 2	17.36	6.66	20.70	11.42
pH values				
Trial 1	6.70	6.60	6.70	6.70
Trial 2	6.50	6.50	6.50	6.60
Color values				
Trial 1	4.3YR 6.0/3.6	4.0YR 5.6/3.8	4.5YR 6.2/3.4	3.5YR 5.6/3.9
Trial 2	5.0YR 5.9/3.3	3.8YR 5.7/3.7	5.3YR 5.9/3.3	4.5YR 5.3/3.9
Tensile strength				
Trial 1	469	724	418	394
Trial 2	461	579	478	367
Flavor preference				
Trial 1	5.9	5.4	4.4	6.7
Trial 2	5.4	5.6	5.4	5.9
Juiciness difference				
Trial 1	7.2	5.3	6.9	8.5
Trial 2	6.1	7.4	7.5	6.3
Texture-tenderness difference				
Trial 1	8.7	5.1	8.1	6.7
Trial 2	7.9	5.0	7.4	7.4

Table 3. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna from comparison III (continued)

Batch #	Phosphate			
	Reg. bind 13	Low fat 14	High fat 15	Low bind 16
% Yield				
Trial 1	95.25	93.17	95.46	93.49
Trial 2	95.07	92.40	95.14	92.75
% Shrink				
Trial 1	7.77	8.57	8.26	8.78
Trial 2	9.63	8.78	10.74	10.07
% Moisture				
Trial 1	60.64	70.04	57.99	66.98
Trial 2	59.08	70.22	57.84	65.92
% Protein				
Trial 1	14.05	17.01	13.18	15.42
Trial 2	13.53	18.03	12.97	14.72
% Fat				
Trial 1	21.81	9.18	25.12	14.01
Trial 2	24.34	8.44	25.78	15.42
pH values				
Trial 1	6.80	6.65	6.70	6.70
Trial 2	6.70	6.55	6.60	6.60
Color values				
Trial 1	2.8YR 6.3/3.5	1.7YR 5.7/3.8	3.2YR 6.3/3.4	1.8YR 5.5/3.5
Trial 2	3.9YR 6.0/2.9	3.1YR 5.7/3.6	4.1YR 6.0/2.8	3.0YR 5.9/3.6
Tensile strength				
Trial 1	630	1,322	439	414
Trial 2	547	1,025	623	828
Flavor preference				
Trial 1	7.3	7.1	7.0	7.1
Trial 2	6.7	6.3	6.3	6.9
Juiciness difference				
Trial 1	6.6	7.2	9.3	6.9
Trial 2	8.4	4.7	9.8	8.2
Texture-tenderness difference				
Trial 1	6.5	3.7	8.4	6.0
Trial 2	7.0	3.5	7.2	4.5

Table 4. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna and thuringer from comparison IV

	Bologna			
	3.5% NFDM	3.5% NFDM+P	3.5% FNFDMP	7.5% FNFDMP
% Yield				
Trial 1	94.18	93.98	93.38	90.29
Trial 2	96.12	95.85	95.58	94.22
% Shrink				
Trial 1	9.24	9.01	9.02	9.51
Trial 2	8.72	8.60	8.30	8.19
% Moisture				
Trial 1	63.46	62.66	61.93	60.90
Trial 2	65.78	64.58	64.21	63.56
% Protein				
Trial 1	15.56	15.00	15.16	16.06
Trial 2	14.41	14.22	14.19	14.88
% Fat				
Trial 1	16.79	17.48	18.22	16.87
Trial 2	15.84	16.57	17.12	15.74
pH values				
Trial 1	6.1	6.1	5.7	5.4
Trial 2	6.4	6.4	6.0	5.7
Color values				
Trial 1	1.6YR 6.1/3.5	1.5YR 6.0/3.7	1.5YR 6.0/3.6	1.6YR 6.2/3.5
Trial 2	1.7YR 5.8/3.3	1.7YR 6.0/3.2	1.8YR 6.2/3.1	2.0YR 6.0/3.0
Tensile strength				
Trial 1	655	811	704	175
Trial 2	655	744	732	261
Flavor preference				
Trial 1	7.3	6.9	7.2	5.7
Trial 2	7.5	7.1	7.2	5.7
Juiciness difference				
Trial 1	8.8 ^a	8.2	9.2	10.3
Trial 2	8.9 ^a	7.9	10.3	9.7
Texture-tenderness difference				
Trial 1	9.0 ^a	7.5	10.4	13.0
Trial 2	9.5 ^a	7.7	8.5	10.9

^aToo brittle for testing

Table 4. Mean values for yield, shrink, moisture, protein, fat, pH, color renotation, tensile strength, flavor, juiciness, and texture-tenderness of bologna and thuringer from comparison IV (continued)

	Thuringer			
	3.5% NFDM+C	3.5% NFDM+C+P	3.5% FNFDM+P	3.5% FNFDM
% Yield				
Trial 1	84.01	83.61	81.04	80.49
Trial 2	84.69	84.59	83.12	79.21
% Shrink				
Trial 1	4.80	4.74	6.32	6.30
Trial 2	5.10	4.90	5.02	6.30
% Moisture				
Trial 1	61.94	61.51	58.70	63.09
Trial 2	62.98	62.08	60.86	60.54
% Protein				
Trial 1	16.06	16.00	18.19	18.50
Trial 2	16.44	16.25	16.69	19.00
% Fat				
Trial 1	17.56	17.67	18.34	13.70
Trial 2	15.90	16.54	17.14	15.92
pH values				
Trial 1	4.7	5.1	4.6	4.3
Trial 2	4.6	4.9	4.6	4.3
Color values				
Trial 1	1.0YR 5.3/3.9	1.2YR 5.5/3.5	1.8YR 5.5/3.7	1.0YR 5.5/3.8
Trial 2	1.5YR 5.4/3.6	1.0YR 5.9/3.7	1.8YR 5.7/3.3	1.7YR 5.8/3.4
Tensile strength				
Trial 1	333	579	-- ^a	--
Trial 2	361	390	--	--
Flavor preference				
Trial 1	6.3	7.1	4.3	3.5
Trial 2	4.6	5.5	4.5	3.9
Juiciness difference				
Trial 1	8.9 ^b	7.7	9.7	9.4
Trial 2	8.6 ^b	8.1	9.2	9.7
Texture-tenderness difference				
Trial 1	9.0 ^b	7.8	12.0	12.4
Trial 2	9.1 ^b	8.5	10.0	11.1

^aToo brittle for testing

^bStandard for bologna

^cStandard for thuringer

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