REPLACEMENT OF MEAT BY VEGETABLE FATS AND PROTEINS IN SEMI-DRY SAUSAGES

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ABSTRACT

In the preparation of a semi-dry sausage type of product, meat protein and fat were replaced with equivalent levels of 'Promine-D'[1], an all-vegetable protein and 'Crisco' Shortening[2], an all-vegetable fat, both individually and simultaneously to a level of 50 per cent. The sausage batter was conventionally prepared, stuffed into collagen casing, smoked to an internal temperature of 140°F and matured for ten days at 15°C. The resulting product was evaluated for color, texture, morphological characteristics as well as for keeping quality.

The role of 'Promine-D' as a meat extender or improver at a level when it supplied 10 per cent of the protein in the sausage batter was confirmed.

No improvement in either the physical or organoleptic properties of the semi-dry sausages was achieved by replacing the meat fat alone with shortening at a level of 10 per cent or simultaneously with meat proteins at the same level.

When both meat proteins and meat fat were replaced either individually or simultaneously beyond the 10 per cent level, gross deterioration in the physical, morphological and organoleptic properties was displayed.

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[1] 'Promine-D' supplied by Central Soya, Chemurgy Division, Chicago, Illinois.

[2] 'Crisco' Shortening, product of Procter & Gamble, Toronto, Canada.

Relative stability over a reasonable period of time was achieved with the low level of residual moisture in the ripened sausages.

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INTRODUCTION

World production figures for livestock and livestock products in seven regional groupings of the world showed a marked deficit in those parts of the world generally regarded as underdeveloped (F.A.O., 1966). Yet, relatively balanced rich protein requirements for human nutritional needs are best met from these sources. This problem is further complexed by the grim fact that the rate of increase in world population follows a geometrical pattern while the pattern of increment in world food production is at best arithmetical. This imbalance poses immediate problems in world feeding.

In recent years, much attention has been focused on the direct utilisation of processed high quality proteins and fat from plant or synthetic sources as these are essential to human nutrition in the future. The high protein and oil contents of soy bean have received a more diverse use than those of any other crop, their use as nutritive boosters, food supplements or as foundations for 'tailored' foods being well established following the evolution of very efficient means of inhibiting the anti-tryptic factor present in the raw seed. Other sources of processed vegetable proteins and fats which are of

potential importance in this respect and which are native to the food deficit areas include peanut and cotton seed.

This investigation was undertaken to evaluate the possible utilisation of a few such processed plant proteins and fat, namely, 'Promine-D', 'Livelong V.P.' and 'Crisco' Shortening, in a semi-dried sausage (Pepperoni) type product for possible use as meat supplements or replacements in Nigeria and perhaps other developing countries. The effect of their use on sausage characteristics such as color, texture and organoleptic properties were also investigated.

LITERATURE REVIEW

Sausage as a Food

The origin of sausages as a form of processed meat food dates far back into history. Various forms of sausages such as Tomacina and Circelli were well known during the era of the ancient Roman Empire. The word 'sausage' could be traced to the Latin word 'salsus' meaning salted (Gerrard 1960). This might indicate that these early sausages were heavily cured and of the dry type necessary for preservation over long periods of time. At the present time various forms of dry sausages are known. All the various forms of salami such as Genoa, Leona and Milano can be associated indirectly with the ancient town of Salami from where it is thought to have originated. Other types of dry and semi-dry sausages include metwurst, pepperoni, mortadella and lyon sausages.

Essentially a sausage is a food prepared from seasoned comminuted meat and stuffed into a relatively symmetrical casing. Originally, meat for sausage production were derived from the by-products of animal carcases for which direct utilization was undesirable. The present day high demand for sausage products makes

this discrimination unnecessary. Depending on the processing technique, sausages could be loosely classified as fresh, cooked or smoked and dry. Fresh sausages which are uncooked, and are therefore readily perishable require a high degree of refrigeration during their short shelf life. Cooked and smoked sausages must also have some degree of refrigeration for any extended shelf life. To a large measure, the relative stability associated with dry sausages derive mainly from the protection afforded them by the combined effect of the mixture of curing salt, the extent of smoking to which they are subjected and the degree of partial dehydration which may occur during sausage maturation. In recent years an increasing use of soybean protein concentrates in sausage products and other forms of comminuted meat have been widely accepted. However, scientific reports of their effect on the observable characteristics of semi-dry sausages are few.

Physico-Chemical Effects of Sodium Chloride, Nitrite and Nitrate

Curing as presently known involves the addition of salt, nitrate, nitrite, sugar and other ingredients for the main purposes of preserving and flavoring meat products. From a chemical point of view, these agents exhibit

extremely different functions in prepared comminuted meat products.

MacKenzie in 1964 listed one of the major functions of salt in sausage products as its ability to solubilise and release myosin from the muscle fibre, a step necessary in the preparation of true emulsions.

Various workers have elucidated the exact role of sodium chloride in sausage production (Hansen (1960), Swift et al (1961), Swift et al (1963), Carpenter et al (1964), Saffle et al (1964) and Christian et al (1967)).

Hansen (1960) using prepared microscopic slides and staining techniques on prepared emulsion of pork fat in both water soluble proteins and salt soluble proteins from beef showed that a more stable emulsion was formed by the salt soluble proteins. He observed that fat globules in the salt soluble proteins were covered with a thin deeply staining protein film while the fat globules in the water soluble protein preparations resulted in clear holes in the stained protein film. The photomicrograph further showed that a concentration of protein was not apparent at the fat globule surfaces.

In 1961, Swift et al investigated the capacity of meats to emulsify fats. Using various volumes of 1M saline solution to extract the same amount of meat, they demonstrated that with increase in the total volume of saline solution used, the corresponding increase in salt soluble protein extracted was capable of emulsifying an increasing amount of fat. In another phase of their investigations, they also established an inverse and curvilinear relationship between the efficiency of the salt-soluble proteins in the extracted slurry on one hand and both the amounts of protein removed from the solution and the original protein contents on the other. Their data also demonstrated that while 84.5 per cent of the salt soluble proteins were removed from the solution during the process of emulsification, only 66.6 per cent of the water soluble proteins were so removed thus indicating that salt soluble proteins were more completely utilised than water soluble proteins in emulsion formation.

In a different study Swift et al (1963) investigated those factors affecting meat proteins as emulsion stabilizers. In particular, they studied the effect of pH and

sodium chloride on water soluble and salt soluble proteins and found that at pH ranges between 4.0 and 7.85, the emulsifying capacity of the water soluble proteins increased with increasing concentrations of sodium chloride but that they exert their maximum activity at a lower pH (5.2) than is normally obtained in meat (pH = 5.6) and at a higher salt concentration than is desirable for flavoring purposes. In contrast to these observations on the emulsifying capacity of the water soluble proteins, they observed a corresponding increase in the emulsifying capacity of salt soluble proteins with increasing concentrations of sodium chloride at pH values ranging from 5.4 to 6.0. This pH range is within the normal range of pH for fresh meat (5.3 to 6.0). Thus the role of the sodium chloride during curing of meat would be to extract the salt soluble proteins and make them available for emulsion formation.

In 1964, Carpenter and Saffle using a model system extracted the salt soluble proteins from eighteen types of meat normally utilised in sausage production and determined their relative emulsifying capacity. Results from their investigations were used to classify these meats

accordingly. They demonstrated that meat with high contents of salt soluble proteins had the highest ability to emulsify oils.

Saffle et al in 1964 investigated the role of salt in sausage production along a different line. In determining the effect of heat on the migration of chemical constituents of frankfurters, they smoked two batches of frankfurters for two hours at 130°F and 170°F respectively cooled the sausages with a spray of cold water to a temperature of 70°F after which they removed from both batches a 3-mm-diameter sample from the centre and a 1-mm-thick sample from the surface for chemical analysis. It was observed that more protein was located in the surface sample than in the centre sample at both temperatures. They accounted for this difference by suggesting that more salt soluble protein migrated to the surface and was deposited there as moisture was evaporated from the product. They also observed a higher level of soluble protein in the 1 mm outer zone of the frankfurter smoked at 130°F. Apparently, the cumulative effect of the salt and higher temperature reached within the frankfurter at a processing temperature of 170°F was adequate to gel the

protein before appreciable migration outwards could occur.

Christian and Saffle in their investigation in 1967 used a model system of salt soluble protein extracted from bull meat with 1M. salt solution to determine the degree of emulsification of various fats and oil. Their data indicated that fatty acids are less emulsified than vegetable oils or animal fats. They further observed significant difference in the level to which six types of vegetable oils could be emulsified. These differences were less marked with respect to the emulsification of animal fats.

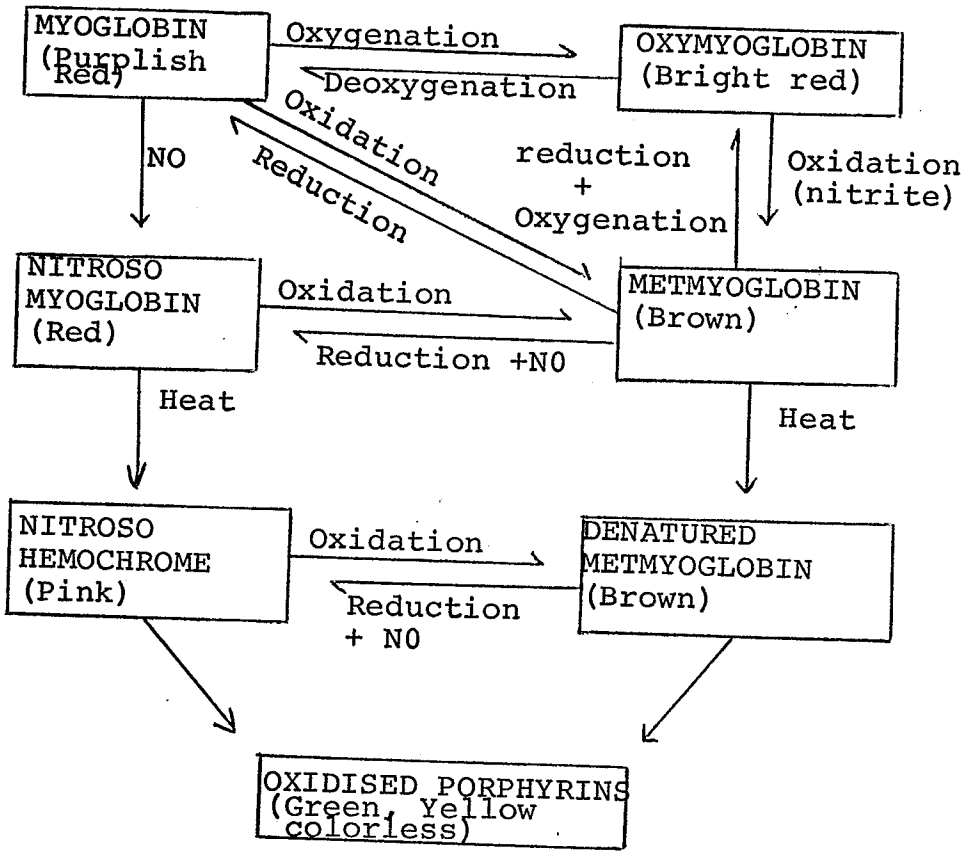
In contrast to the important physico-chemical role of sodium chloride in stablising sausage emulsions, both sodium nitrate and nitrite exhibit straight chemical reactions with the meat pigments. Essentially sodium nitrate, sodium nitrite and to a lesser extent, potassium nitrite are utilised in the curing salts. Aqueous solution of nitrites are highly ionised and slightly alkaline. The highly reactive nitrite ion can serve both as a reducing and as an oxidising agent (AMI 1960). Its reducing properties are of less importance in meat curing although

it is known to be oxidised to nitrate ion by such oxidising agents as bromine, permanganate, chromate and others. However, in an acid environment, nitrite exists in equilibrium with nitrous acid which may itself be reduced to nitric oxide. AMI in 1960 using a curve based on the Henderson-Hasselbach equation, pH = pKa + log (salt)/(acid), showed that only a small quantity of the added nitrite exists as nitrous acid in the pH range of meat. Added nitrate in the curve is progressively reduced to nitrite which is in turn available for chemical reactions in meat.

The complex of nitric oxide with myoglobin results in the formation of nitrosomyoglobin which is responsible for the red colour of uncooked cured meats. In sausage manufacture, this process is delayed as the meat may be ground prior to the incorporation of the cure. The oxygenated heme pigment formed at this stage is reduced and then combined with the nitric oxide to yield the red pigment, nitrosomyoglobin. This intermediate compound is further converted to the more stable form nitric oxide-myochromogen on heating or smoking to higher temperatures (Figure 1).

Figure 1

COMMON COLOR CHANGES DURING MEAT CURING[3]



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[3]American Meat Institute Foundation, The Science of Meat and Meat Products, W.H. Freeman and Company, San Francisco 1960.

Toxigenicity of nitrite at high levels delimits the level which can be added to meat, although the actual nitrite which can be recovered from meat has little or no bearing on the amount originally added. White et al in 1940 heated samples of Wiltshire bacon at six different temperatures (20, 40, 50, 60, 70 and 80 degrees C) and for four different heating periods (5, 10, 20 and 40 hours) and then compared them for colour and nitrite contents. They observed the highest increase in nitrite content at $40^{o}C$ and suggested that the added effect of microbial activity might play some role in the nitrite production. They also observed marked reduction in nitrite content above $55^{o}C$ probably due to chemical reactions between the nitrite and meat constituents.

In 1953, Rose et al suggested that the reducing systems in the meat significantly affect the final nitrite level of the meat. In their experiment, a slurry prepared from psoas muscle was buffered with McIlvaine's citric acid-sodium phosphate solution. The suspension was held overnight at $40^{o}F$, then warmed to room temperature after which it was treated with a sodium nitrite solution. It was then incubated for five hours at $110^{o}F$. A control

and a duplicate sample for analysis at zero hour were also prepared. The workers determined nitrogen by the micro-Kjeldahl technique and oxidation-reducation potentials with 2-6-dichlorolbenzenone indophenol. Their findings indicated that nitrite is not bound to the meat protein. They also observed a loss of nitrite from the pork suspension with increasing temperature. This finding was also reported earlier, by White et al(1940). This destruction of nitrite was attributed to a limitation by some compounds which are capable of transferring electrons across the gap in potential between the nitrite-nitric oxide system and that of the meat. Added hemoglobin was observed to increase the relative destruction of nitrite thus confirming that in the pH range of meat, this ferric-ferrous carrier system would be the main limiting compound which removes nitric oxide from the system at the expense of the nitrite.

Studies along a different line involving the quantitation of the amount of meat pigments reacting with the nitrite during the curing process were carried out in 1963 by Tauber et al. In their experiments, three frankfurter emulsions calculated to contain 64, 46 and 81 μg pigment per gram of meat block were smoked to an internal temperature of 152^{o}F in two one-quarter hours after which both the total and the cured meat pigments

were determined by a procedure previously outlined by Hornsey in 1956. The total pigments were extracted as the acid hematin and measured spectrophotometrically at 640 mμ while the cured pigments were extracted as acetone-nitrosoheme and similarly measured at 540 mμ. Their results indicated that in the three prepared emulsions, 93, 85 and 96 per cent of the total pigments respectively had reacted to form the nitric oxide myochromogem. They also found similar ratio when commercial frankfurters from different sources were analysed. By varying the smoking temperatures in another series of experiment these workers determined that as cooking temperature was increased from 170°F to 210°F, there was a rapid increase in the rate of formation of the cured meat colour. They also developed a temperature-time relationship for the maximum development of the cured meat colour from which it was possible to deduce that further time was required beyond the attainment of the 152°F internal temperature for complete colour development. Apparently, this period was required to maximise the complete reaction of the nitric oxide with myoglobin and perhaps to allow for the complete denaturation of the protein moiety of the pigment.

The Effects of Sodium Chloride, Sodium Nitrite and Sodium Nitrate on Micro-organisms

Apart from bringing direct colour changes in cured meat products, the addition of sodium chloride, nitrite and nitrate to such meat items are known to bring about both qualitative and quantitative changes in the bacterial population. It is well recognised that a high level of contamination does affect the organoleptic qualities of processed comminuted meats. Niven in 1951 demonstrated that high levels of contamination of raw meat and other sausage ingredients may result in green core development.

Halleck et al in 1956 carried out exhaustive studies in determining the quality and quantity of the bacterial flora of prepackaged fresh meats stored at refrigeration temperatures. Their studies indicated that organisms of the non-pigmented Achromobacter-Pseudomonas type and members of the genus lactobacilli were prevalent during the first two weeks at these temperatures while Pseudomonas fluorescens was more favoured at the latter stages of storage. Their result showed that storage at these temperatures resulted in a total bacterial load in the range of five to six log cycles at ten days.

In a later experiment by Warnecke et al in 1966, the effect of various levels of contamination of raw material on processing characteristics, acceptability and

colour development of processed bologna was studied. They reported a higher value of nine log cycles for the bacterial load of uncooked meat stored for ten days at 9°C. They also reported that the high level of contamination imparted some effect on the flavour of the processed bologna.

From the point of view of these changes in the microbial growth during meat storage and which are known to affect the processing characteristics of sausages, the effects due to the curing agents are of special interest. Studies on the preservative effects of sodium chloride, sodium nitrite and sodium nitrate have been conducted by various workers (Steinke and Foster, 1951, Bulman and Ayres, 1952, Silliker et al, 1958, Shank et al 1962, Pivnick et al, 1967, Duncan and Foster, 1968 and 1969, and Scheurer 1968).

The extent of germination and toxin production in liver sausages inoculated with C.parabotulinum was investigaged by Steincke and Foster in 1951 who reported that both salt and nitrate in combination were capable of inhibiting toxin production but noneof them in isolation could effectively inactivate the organism from producing toxins.

In 1952, Bulman and Ayres studied the inhibitory effect of sodium chloride, sodium nitrite and sodium

nitrate on spores of Clostridium botulinum. Samples of prepared meat emulsion containing various levels of salt, nitrite, nitrate and a mixture of the mixed curing salts were inoculated with spores of Clostridium botulinum. They observed that increasing the salt content to six or eight per cent level preserved samples inoculated with 175 spores for ten months at 37°C. A decrease in the salt content decreased the shelf life while decreasing the level of contamination decreased the salt level required for preservation. A possible interference of the salt with the enzyme system was suggested as the mechanism for preventing spore germination. Mixed reactions were obtained for effects due to nitrate. Inhibitory effects were observed at 3.5 per cent level of sodium nitrate on anaerobic spoilage over a twelve week period. Aerobic spoilage was observed within one week probably due to the gradual generation of oxygen from the nitrate. Results with the nitrite were remarkable. These workers established that an extremely low level of nitrite in the range of 0.04 to 0.08 per cent $NaNO_2$ was sufficient to inhibit spore germination and vegetative growth although the gradual loss of nitrite over very long storage period may eventually result in observable spoilage.

Using canned cured meat, Silliker et al in 1962 demonstrated that within organoleptically acceptable limits

of salt and permissible levels of nitrate and nitrite, stability of lightly processed cured meat could be attributed to a large measure to the nitrite content which primarily inhibited the germination and/or the effective outgrowth of heat injured spores. Added nitrate on the other hand appeared to play no role in the microbial inhibition. In fact an increase in product spoilage due to the genus Bacillus was observed.

Shank et al in 1962 investigated the effect of the various oxides of nitrogen on bacteria. They demonstrated that pure nitric oxide had no inactivating effect on bacteria cells and spores were inactivated by nitrogen dioxide. Direct maximum bactericidal effect of nitrite was observed at pH 4.5 to 5.5 and a distinct bactericidal effect at pH 5.6 to 5.8. At higher pH, nitrite appeared to favor bacterial growth. The authors indicated that at pH range from 4.5 to 5.5, nitrite bactericidal activity was due to its occurrence principally as nitrous acid.

Pivnick et al in 1967 demonstrated that heat injury of spores was not necessary for sodium nitrite to inhibit toxinogenesis due to Clostridium botulinum types A and B and that although toxinogenesis may occur in smoked fish, semi-preserved meats are unlikely to cause botulism.

Recently the exact mechanism by which both sodium chloride and sodium nitrite inhibit both spore germination and vegetative growth was elaborated by Duncan and Foster in 1968. They observed that at levels above 0.01 per cent sodium nitrite, bacteria spores lost their refractility and cell division of vegetative cells were inhibited. With sodium chloride at the levels used, its effect on the spores were mixed. It is generally believed that heat treatment may not be completely lethal to bacteria spores in cured meat although the damage which occurs during this process may be sufficient to prevent their further growth and multiplication. These two workers further reported that heat damaged spores were less tolerant to curing salts than were unheated spores. At low salt concentration, protective effects against heat damage appeared to occur while at the higher salt concentrations, inhibitory effect appeared to be predominant.

Unlike in cured chunks of meat, the process of emulsification involved in sausage production is largely instrumental in uniformly dispersing the curing salt throughout the batter thus affording greater protection.

Commercial Smoking Process

The art of smoking has been used for centuries in the preservation of flesh food. This process subjects the food to the chemical component of the smoke, the elevated temperature prevalent in the smoke house and to the drying effect. The advancement in the technique of refrigeration has greatly minimized the effect of the latter. The modern day function of smoke is therefore primarily to impart characteristic smoked flavor to the products. Conventionally, smoking may be carried out by either the cold or the hot process. In cold smoking the temperature attained in the smoking chamber does not exceed $90^{o}F$ and is carried out over a prolonged period. Hot smoking is generally completed within a few hours during which a temperature not below $140^{o}F$ is attained within the smoked product.

Smoke Production

From a commercial point of view, smoke can be produced by burning dampened saw dust or chipped fresh woods, burning dry saw dust continuously and by friction. Various methods for generating smoke have been described by various workers (Hanley et al, 1955a; Hanley et al 1955b; Anon, 1956; Nichol 1960; Lantz and Young 1949 and Lantz 1969).

In 1955(a) Hanley et al described a method of electrostatic precipitation whereby smoke was passed through a zone of high electrical potential before being directed

to a suspended product. Another method described by Hanley et al 1955(b) involved the combined use of infrared heating zones and a chamber for electrostatic deposition of smoke on flesh foods. Anon in 1956 elaborated on the use of the friction generator in which smoke is produced by pressing the end grain of a hardwood block against a rotating carbide-tipped disc. A procedure utilising the principles of fluidised bed was described by Nichol in 1960. Dry saw dust was fluidised with air or other inert gas and fed continuously into a hot chamber to evolve smoke. Lantz and Young in 1949 described an air conditioned tunnel designed primarily for fish but which could be adapted for other fleshy food. Lantz in 1969 also described a simple smoke chamber which could be operated with very little overhead cost. Draught in 1963 mentioned the advantages of liquid smoke materials prepared through the burning of hardwood saw dust as is commonly done during meat smoking.

Physical, Chemical and Microbiological Effect of Smoke

The high temperature reached during the smoking operation is often sufficient to denature proteins, inactivate enzymes and destroy a relatively high proportion of the microbial contaminants in the food. The effect of heat on the stabilisation of the pink colour of nitric-oxide hemachromogen has been discussed. Other effects of smoke depend on such factors as the smoking temperature, smoke

density, chamber temperature, air flow rate, chamber humidity and the type of wood used to generate the smoke.

Gibbons et al in 1954 reported that a 10,000 fold reduction in bacterial load could be achieved with the combined action of heavy smoke and high temperature and that this reduction depends on the length of exposure. A residual effect on inoculum introduced after the smoking was completed was also observed. Watts and Faulkner in 1954 using an artificial system demonstrated that the smoke constituents also impart an antioxidant effect on lard. Results of an experiment carried out by Erdman et al in 1954 on fatty fish fillets demonstrated both the antioxidant and bactericidal effect of smoke.

The observed inhibitory effect of smoke on bacterial growth and fat deterioration as well as its characteristic effect on smoked food flavor, has heightened interest in those chemical fraction of smoke which directly bring about these changes. Husaini and Cooper in 1957 utilised a laboratory smoke generator coupled with four traps which were bathed in a mixture of alcohol and dry ice to fractionate the chemical constituents of liquid smoke. Volatile acids were steam-distilled, purified and fractionated on a silicic acid chromatographic column. The separated acids were eluted and identified mainly as butyric, propionic, acetic, formic and two other unidentified acids.

In a similar experiment carried out in 196 Hamid and Saffle recovered smoke constituents from hickory wood with 1.0N NaOH and analysed the trapped compounds with a flame ionisation gas chromatographic unit. In addition to the four acids positively identified by Husaini and Cooper, these workers also identified iso-valeric, n-valeric, iso-caproic and n-caproic acids. Other smoke constituents include tar, wood resins, high boiling compounds of the phenolic type which are responsible for the antioxident and bactericidal effect and a few lower boiling compounds. Most of the flavoring materials in smoke is contained in the steam distillable fraction particularly the phenols, acids and carbonyls, such as formaldehyde and acetaldehyde.

In an experiment carried out in 1966, Hamid and Saffle used a model glass smoke house and seven volatile acids to demonstrate the extent of smoke penetration into meat. Their results indicated a penetration depth of between ten and twelve millimeters below the meat surface. Thus in a small diameter sausage, sufficient penetration of the smoke constituents to all parts is easily achieved.

The Effect Due to Spices

The functionality of various spice mixture in improving the flavor and satiety of sausage type products is well recognised. Heath in 1968 indicated that such spices as Rosemary, Thyme and Bay Laurel significantly retarded color fading and loss of bloom especially in uncooked sausages. Observations of antioxidant effect in meat have also been made of the ground herbs, spice extractives and dry soluble spice preparations made from them.

From a preservative point of view the bactericidal effect of the naturally occuring phenolic content have been recognised. However untreated spices are normally infested with heavy loads of micro-organisms. Commercial spices do receive various forms of sterilization of which gaseous sterilization with ethylene oxide appears to be the most important. The sterilizing effect of gaseous ethylene oxide have been discussed by Ernst and Shull in 1962 while toxicity due to this compound have been discussed by Wesley et al in 1965. Robinson et al in 1954 reported the complete radiation sterilization of certain spices with 10^6 rep of soft X-rays. The physical effect of spices in sausage type products vary. Ground spices generally increase the water absorption of the meat mixture. Depending on the type, granular size, quantity and temperature, the spices may improve to a slight extent the emulsifying effect. As

low molecular flavor substances are more firmly bound to the meat structure, ground spices generally possess a low diffusion rate, hence the need for proper mixing during emulsion formation.

Meat-like Processed Vegetable Proteins

The inadequate supply of animal proteins in many parts of the world has received widespread attention within the last decade. Attention has therefore been focused on the direct utilization of concentrated plant proteins in such forms simulating their animal protein counterpart. Sources of these concentrated proteins vary although main interests in proteins for meat-like products have been focused on the major oil seeds; soya bean and to a smaller extent cotton seed and peanut. A comparison of world production of these oil seeds with a few other plant proteins is featured in Table 1.

Purification of Plant Proteins (Soy Proteins)

For the most part, the unique food products which possess the distinct eating quality and fibrous texture simulating those of meat or such other products which have received wide applications in meat food products have been based on extracted proteins from soy bean to which the major part of this review is confined. Liener in 1958 showed that the proteins in raw soy beans have low nutritive value and that cooking brings this value close to those of

Table 1

WORLD PRODUCTION OF PLANT-PROTEIN SOURCES* (1965)

Commodity	Annual Production (1,000 metric tons)	Average Protein Content	Average Available Protein (1,000 metric tons)
Soy beans	36,641	38	10,500
Peanuts	15,315	25	3,470
Cotton Seed	21,851	20	3,180
Sesame	16,203	25	437
Sunflower seed	7,931	20	280
Total Oil seeds	97,941		18,867

*Data from: F.A.O. Production Year Book 20 Rome 1966.

meat and milk. Muelenaere in 1964 demonstrated that soy bean trypsin inhibitors are one of the major factors responsible for the poor utilization of the proteins in raw soy beans. Some of the factors affecting the inactivation of these trypsin inhibitors were investigated in 1966 by Rackis who determined that improvement in the nutritive value of soy bean meal coincides with the decrease in trypsin inhibitor activity brought about by moist heat treatment. Steiner and Frattali in 1969 re-characterised two of these inhibitors; Bowman-Birk inhibitor and Kunitz inhibitor, both of which are thermolabile to moist heat. Other known antinutritional factors in soy bean include hemaglutinin, saponin, goitrogenic factor, anticoagulant factor and lipoxidase.

It is believed that the present methods of extraction of soy bean proteins largely inhibit the antinutritional factors as well as almost completely deflavor and deodorize the extracted meal. Applicable methods of extraction were reviewed by Noyes in 1969. These include solvent extraction at high temperatures using hexane or absolute ethyl alcohol followed by the isolation of the soy protein from the extracted meal by solubilization in an acid, alkali or salt solution and a consequent precipitation of the protein from the solution. Kuramoto in 1966 described a procedure whereby hexane extracted flakes were washed with

either ethanol or propanol and subjected to vapor desolventizing. These were slurried in ten to twenty times its weight of water at pH 6.5 to 9.5 to remove the soluble proteins which were then precipitated from separated solutions at pH 4.5 to 5.2 with acetic acid. Further purification has been achieved through ion-exchange refining, treatment with protonic acid, various peroxides and infra-red heating (Noyes, 1969). In all these cases solvent extractions were preceded by a process of cracking, dehulling and flaking. Other procedures for extraction and purification of soy bean proteins to achieve bland, odorless and colorless products with desirable physical, chemical and functional properties abound in the patent literature.

Nutritional Value of Soy Proteins

The concentration and isolation of soy bean protein to a large measure frees this product from the insoluble fibre, soluble carbohydrates, and other non-protein materials in the meal. Nutritionally, soy bean protein freed of its tryptic inhibitors and other anti-nutritional factors, increases the amount of protein when used as a food additive, provides for a better balance of amino acids normally present in a high quality protein. Of all the essential amino acids necessary for growth, only methionine appeared to be limiting in soy protein. Table 2 compares the amino acid contents of isolated soy protein and of beef muscle.

Table 2

AMINO ACID COMPOSITION OF SOME ISOLATED SOY PROTEIN[a] AND BEEF MUSCLE

Amino Acids	Isolated Soy Proteins 1	2	Beef Muscle[b]
	grams per 16 gms of Nitrogen		
Arginine	8.2	7.8	6.5
Cystine	0.7	1.04	1.3
Hystidine	2.6	2.46	3.5
Isolencine	5.8	4.85	5.3
Lencine	8.4	7.74	8.2
Lysine	6.0	6.06	8.6
Methionine	1.4	1.06	2.5
Phenylalanine	5.8	5.37	4.1
Threonine	4.0	3.70	4.4
Tryptophan	1.1	1.35	1.2
Tyrosine	-	3.71	3.4
Valine	5.8	4.81	5.5

Ref. a(1) "Tech. Literature" The Glidden Co., Chicago, Illinois

(2) "Tech. Service Bulletin on Promine" Central Soya, Chem. Div. Chicago, Illinois

b M.L. Orr and B.K. Watt, U.S. Department Agr., Home Economics Res. Report 4 (1957)

Kwong and Barnes in 1963 investigated the effect of trypsin inhibitors on methionine and cystine utilization in rats. Their findings indicated that soy bean contains enough cystine but not methionine to satisfy metabolic requirements. Evans et al in 1951 showed that overheating soy beans during processing resulted in a loss of cystine so that this amino acid first became limiting. In 1958 Circle and Johnson reported a clinical study by Szujewski in which a daily ration of 8 to 10 gms. of soy protein was supplied to each of over 200 persons with various illnesses and covering all age groups. His report confirmed no undesirable effects due to this protein as all the patients favourably tolerated the soy protein.

In 1966, Iriarte and Barnes studied the effect of overheating on certain nutritional properties of soy bean proteins. Their investigations showed that both lysine and cystine served as the most sensitive indicators of over-heating soy bean during extraction. Modern extraction procedure utilizing low temperature solvent extraction coupled with acid precipitation has to a large measure reduced this limitation of its nutritional aspect. That the basic soy protein provides a good source of the B-complex vitamins, choline, calcium, iron, phosphorus, potassium and traces of the other essential minerals is also well recognised.

Soy Proteins and the Meat Industry

Rakosky in 1969 observed that soy proteins serve as a natural adjunct in processed meats as they are high in nutritious protein which are utilizable as meat protein complements, improve meat juiciness and are cost saving. Some of these products also possess both emulsifying and binding properties.

Sausage Supplements

Of particular interest in the sausage industry are soy flour, soy grits, soy protein concentrates and isolated soy proteins. The protein contents vary, being about 53 per cent in soy flour and soy grit rising to 92 per cent in 'Promine-D', a typical isolated soy protein. This renders them less expensive than meat. Both soy protein concentrate and isolated soy protein are available commercially in various forms, each with its own specific functionality such as moisture holding capacity, emulsifying and meat binding abilities, as well as heat stability and heat-gelling abilities.

In an investigation carried out in 1955, Glabe et al used a laboratory modification of the commercial production procedure for sausage production to incorporate a bland tasting, isolated soy protein, 'Gelsoy'[4] in prepared sausages at a level of 0.5 per cent. The sausages were stored at 40°F for sixteen hours after which the sausages were

[4] 'Gelsoy', product of Swift & Co., Chicago.

sliced lengthwise and observed for water and fat separation. Their result indicated that gelsoy actively served as a fat and water binder as well as contributed to the enrichment of the frankfurter protein. Similar results were observed with meat loaves and canned meat.

Frank and Saffle in their novel study reported in 1959, prepared a non-meat simulated sausage from isolated soy bean protein, all-vegetable shortening, and other processing adjuncts. Their investigations indicated that such a sausage at pH 6.3 had a desirable texture and consistency and was acceptable when the moisture content was 68.7 per cent. They also observed good results with fat content of 4.6 to 17.1 per cent at which level the function of fat as a palatability enhancer was maximum.

Circle in 1964 reported that between 70°C and 100°C, an 8 per cent to 14 per cent aqueous dispersion of isolated soy protein gelled within ten to thirteen minutes but was disrupted at 125°C although this disruption was not observed at a dispersion level above 16 per cent. A review of these proteins was carried out by Ziemba in 1966 and by Martin and Leclair in 1967. The specific roles of these concentrated proteins in forming and stabilizing meat emulsions are reviewed in a later section (Page 46). Various governments regulate the level permissible in sausage products. In the United States, this limit varies between 2 and $3\frac{1}{2}$ per cent.

Application in Other Processed Meats

Coarse soy flour, soy grits and soy protein concentrate have found wide application in such meat items as meat patties, chili con carne, meat balls, salisbury steak, pork and barbeque sauce and a few other items mainly to improve flavor, texture and cooking shrink.

In 1966, Ziemba discussed some refined soy proteins which are presently being used in the meat industry. "Swift's Food Protein" - a bland, granular soy protein concentrate - on hydration is capable of replacing thrice its weight of ground meat with an increase in the net protein content of the final product. Another protein concentrate supplied by Griffith Laboratories when used at a level of $3^{1}/_{2}$per cent in a meat product formulation greatly complements meat protein's emulsifying quality. It has also been observed that on addition of $1^{1}/_{2}$ per cent of soy proteinate to hamburger meat followed by frying, such meat retains its full fat, juiciness, size and shape. Addition of soy isolates to table-ready meats like frankfurters, bologna and others have also been observed to make up for the many variables that influence a meat's binding property. Tests by various manufacturing companies have reported them to be "aiders" in processing other meats like canned luncheon meats, sausage, meat balls, poultry rolls and even in pumping hams.

Simulated Meat Products from Textured Vegetable Protein (TVP)

Pioneering work in this area was done by Boyer in 1954 to produce a texturized vegetable protein possessing the fibrous texture and appearance of natural meat as well as the very important attribute of chewiness. His method involved the dispersion of purified extracted protein in an alkaline medium with or without added color to form a colloid which was forced through a spinneret or die as a dope into a coagulating bath of an acid salt solution at pH 5.6 to 6.4 to produce fibres of pre-determined thickness. These fibres were coated with desirable binders such as starches, dextrins, proteins, gums, alginates, carboxy methylcellulose in the fluid or powdered state. Fat or other flavoring materials may be incorporated before compression to various degrees and slicing. The size of the fibre, their arrangement prior to gelation and the added flavoring and coloring agents made it possible to simulate such meats as pork chop, chicken and turkey meats. Various modifications of this process are described in patent literature reviewed by Noyes in 1969. Meat analogs have also been produced by the thermoplastic extrusion process which requires less purified protein bases.

In 1966, Ziemba reported progress on the production of both a ground beef analog and a bacon analog (Bontrae)[5] from textured spun soy protein water, vegetable oil, egg white

[5]'Bontrae', product of General Mills Inc., Minneapolis.

solids, soy flour, spice, hydrolysed vegetable protein, salt, monosodium glutamate and other specific flavoring agents. These were reported low in fat, free from cholesterol and capable of imparting meaty character to certain products. The attributes of these products were further elaborated by Thulin and Kuramoto in 1967.

Recently, Swift Chemical Company marketed a family of Textured Vegetable Protein under the trade name of Texgram. This dry crunchy material on hydration assumes a chewy character with good water and fat absorption potential and which could be ideally suited for use in any food or beverage in which protein is a component. Particularly, it is very suitable for application in canned or frozen meat specialties.

Most interest in the production of Textured Vegetable Proteins have been based on soy bean as the source material as it contained an initially high level of protein the amino contents of which approximates those of beef muscle. Various other oil bearing seeds and cereals which have appreciable protein portion have also to certain degrees being processed into texturised vegetable proteins which have found some use both in meat and other foods. Of interest in these areas are oil seeds like peanut, cotton seed and such cereals as wheat.

The production of many of the textured vegetable protein is based mainly on the dope spinning process elaborated by Boyer in 1954 and which have been modified by various companies to suit their plant operations. In 1960, Giddey described a procedure whereby defatted peanut meal protein was extracted under alkaline condition precipitated at its isoelectric point with either lactic or hydrochloric acid and mixed with a binder of carrageenin followed by gradual heating to 80^{o}C. The solid portion was then separated by centrifugation and cooled to produce a meat-like material.

A non-spinning process for preparing meat-like TVP was described by Rusoff et al in 1962. Both animal proteins or vegetable protein sources like soy bean meal, peanut, cotton seed or other extracted vegetable meals high in protein content are adaptable for this process. Mainly, the product formed possess a meat-like texture and appearance as well as the ability to be cooked by deep fat frying, roasting, boiling or such other heat treatment that will leave its texture and structure intact.

In a procedure outlined by Elmquist in 1965, protein fibers prepared directly from Safflower were coagulated in a bath of acidified saline solution, stretched, neutralised, washed and coated with a binder containing flavoring and

coloring agents as well as oils. The fibres were heat gelled to produce a meat-like product.

Wheat gluten has also been reported used in preparing simulated meat products which possessed the desirable eating qualities and fibrous texture and in which is incorporated a defatted seed flour or meal prior to heat gelling (Kjelson 1965). A patent taken out in the name of Kjelson and Page also described a process whereby impregnated and partially set up spun protein fibres were subjected to a simultaneous heating and flattening operation to produce a simulated chipped beef type product.

Processed Vegetable Fats and Their Application in Meat Type Foods

The catalytic hydrogenation of various oils converts their component unsaturated fatty acids into a relatively more saturated acids with a corresponding reduction in their iodine values and an elevation of both the melting point and the degree of hardness. Williams in 1966 reported a reasonable resinification of sterols particularly cholesterol in the hydrogenated fat. The desirability of these effects due to hydrogenation is of significance when viewed from its health aspect. Staff (1960) demonstrated that while a distinct association between coronary artery disease and a high intake of saturated fats and animal protein could be made, appreciable lowering of blood cholesterol levels, an index of the incidence of cardio-vascular disease, could be derived by the utilization of vegetable shortening containing higher levels of poly-unsaturated fatty acids and glycerols. Hydrogenated fats are known to contain large amounts of the trans-isomers of the saturated fatty acids which do not occur naturally. The manufacture of all vegetable hydrogenated shortening is governed by a rigid standard for color, flavor, odor, stability consistency and a drastic minimization of the trans-isomer formation.

For most all-vegetable shortenings possessing desirable consistency and body at room temperature, an

iodine value between 65 and 80 per cent coupled with proper blending with a hard stock, plasticizer or highly saturated fat with a maximum iodine level below 15 per cent appears to be ideal. A level of hardstock below 15 per cent appears to be ideal. 'Crisco' shortening containing a blend of hydrogenated soy bean and palm oils (Sargant 1970) derives its hard properties from the glyceride portion of the hydrogenated palm oil. Swern in 1964 indicated that glycerides present in the palm oil normally used as a shortening ingredient occur as solids in their natural state at normal temperatures. The high level of saturation close to 80 per cent with a corresponding low iodine value of 15 obtainable in hydrogenating palm oil to a large measure enhances its plasticizing effect. Hydrogenated soy bean oil with iodine value of 80 and a low saturated fatty acid content of between 15 and 25 also contains between 10 and 23 per cent linolenic acid which has been associated with flavor reversion by Dutton et al in 1953. Specifically, Lenon and Grant in 1947 demonstrated that the hydrogenation of soy bean oil resulted in the conversion of linolenic acid to isolinoleic acid at the middle bond and that this acid rather than linolenic acid in the hydrogenated fat was responsible for the flavor reversion.

The phenolic antioxidant effect of tocopherol naturally present in hydrogenated vegetable shortening is often synergised by the incorporation of either citric acid or phosphoric acids or fortified by the addition of hydroxytoluene and hydroxyanisole. 'Crisco' shortening like most other shortening of its type is from this point of view stable over a reasonably long period, probably due to the additional effect of removing the bulk of the unsaponifiable content by drastic steam deodorization.

From the point of view of meat organoleptic properties, fat serves mainly two functions; the improvement of meat texture and the enrichment of the natural meat flavor and palatability. With respect to metabolic function, fat provides a high degree of the caloric value of meats. From a nutritional standpoint, fat supplies the essential fatty acids, as well as exerting a sparing effect on the B vitamins. Vitamins A, D, E and K are also supplied to a smaller extent. Studies conducted in 1944 by Deuel et al demonstrated that there is little or no significant differences in growth response of rat when fed fat from animal sources and through such sources as corn oil, peanut oil or soy bean oil.

The utilization of processed vegetable fats in replacing meat fat directly in meat and simulated meat items is limited. However, Thulin and Kuramoto in 1967 reported that in the manufacture of simulated meat products,

meat analogs low in saturated fats could be prepared by the incorporation of low melting, or high melting fats of either animal or vegetable origin to levels varying from zero to 50 per cent in beef or similar flavored spun protein.

Finely Comminuted Sausage and Emulsion Formation

It is well recognized that the basis for the formation of a relatively stable and desirable sausage emulsion is the efficient dispersion of the fat component as fine droplets within a surrounding layer of water-protein matrix. Within limits, the major constituents of the sausage batter, water, protein and fat may be regarded as the continuous phase, the emulsifying agent and the discontinous phase. In sausage manufacture, meat tissues are chopped with other ingredients in a silent cutter or any similar equipment. The coupled shearing action of the fast rotating blade and the relatively stationary bowl of the chopper not only disintegrates the meat but helps in releasing myosin, the major salt soluble meat protein acting as the primary emulsifying agent.

Various studies have been conducted to determine the exact mechanism involved in meat emulsion formation and the nature of the emulsion formed. Studies carried out in 1960 by Hansen highlighted certain processes occurring during emulsion formation of a sausage batter. In his experiment, water soluble protein was extracted from beef and pork, salt soluble protein was extracted from fresh pre-rigor beef using a 7 per cent saline solution and clarified pork fat was obtained by centrifuging melted pork fat and then subjecting it to vacuum filtration. The emulsion was

prepared by beating together two hundred mls of protein solution and fifteeen grams of clarified pork fat at $0^{o}C$ until a final temperature of $15.6^{o}C$ was reached. The progress of emulsion formation was followed by removing samples after various periods of chopping and preparing photomicographs of stained frozen sections. Results from this study showed that the fat cells were largely broken up within the first few minutes while the muscle fibres were disintegrated more slowly. It was also observed that an intact skin of protein was formed around the fat globules at the end of emulsion formation. Thus the chopping operation effectively disintegrated and dispersed the fat in the protein slurry during the emulsion formation. It would appear that the salt soluble protein which effectively acted as the emulsifying agent not only lowered the interfacial tension but helped in the formation of a firm protective membrane around the fat globules.

During the emulsion formation, a rise in temperature of the batter is known to occur. At the initial stages increase in temperature partly softens the fat thereby facilitating its dispersion within the protein slurry. Excessive rise in temperature may result in a breakdown in the stability of the emulsion. Studies carried out by Helmer and Saffle in 1963 demonstrated that emulsion breakdown did not occur at any specific temperature but took

place over a relatively wide range in temperature depending on the processing conditions and the type of meat used. However, temperatures around 70°F was determined to be critical in emulsion formation. At higher temperatures, rapid coalescing of the fat globules on contact effectively expedited the emulsion break down.

Studies on such factors affecting the capacity of meats to emulsify fats were carried out by Swift et al in 1961. Ground meat was slurried and extracted with 1 M saline solution, the resulting solution was chilled in an Omni-mixer and diluted,after which melted lard at 30°C was progressively added. It was observed that an emulsion was formed, this persisted and finally collapsed, this transition being featured by a gradual increase followed by a sudden decrease in viscosity. The total volume of fat required to reach this transition was regarded as the emulsifying capacity for the total meat slurried. On the basis of this experiment these findings were reported. The capacity of meat proteins to emulsify fat could be as high as 1.61 gm. fat per mg. protein, maximal stabilisation of emulsion by saline meat extract occurs with optimal comminution of lean tissue followed by the dilution of the saline phase, mixing at low speed, adding fat rapidly and operating at low speed.

That water soluble protein is also involved in emulsion formation was demonstrated in 1963 by Swift and

Sulzbacher who reported an increase in the emulsifying capacity of water soluble proteins with increasing concentrations of sodium chloride. Although not of much practical importance in the sausage industry, emulsifying capacity of proteins in 0.5 M solutions was reported to decrease in the order KSCN, KI, KNO_3, K Br, KCl and K_2SO_4 or the order of the Hofmeister series. Further, close to the iso-electric point of the salt soluble proteins, increasing NaCl content resulted in a significant increase in emulsifying capacity probably due to a more efficient dispersion of the proteins.

The main salt soluble protein of meat involved in emulsion formation is actomyosin, a protein complex derived from actin and myosin. Neither actin nor myosin have been reported to individually stabilize a stable emulsion. Hegarty et al in 1963 observed that the presence of salt greatly depressed the effectiveness of actin as an emulsifier and of myosin to a smaller extent. Also at a pH close to the isoelectric point of actomyosin (5.8) emulsion stablization was maximised due to its increased ability to form a stable interface between the fat globules and the water-protein matrix.

Few information on the stabilization of sausage emulsions with added emulsifiers have been reported. However, Meyer et al in 1964 investigated the effect of

commercial and natural emulsifiers on the stability of sausage emulsion. Sausage batter was conventionally prepared such that test emulsifiers were incorporated at the beginning of the chopping period. The emulsifiers investigated included mono and diglycerides, acetylated mono and diglycerides, diacetyl tartaric esters of monoglycerides and polyoxyethylene sorbitan mono-oleate. Their results indicated a gross reduction in the stability of processed sausage with an increase in the concentration of emulsifier and that greater stability was obtained when the emulsifier was added towards the end rather than at the beginning of the emulsion formation. Probably, the utilization of an emulsifier resulted in small fat particles which rendered the available salt soluble protein insufficient for stable matrix formation.

Processed Plant Proteins and Fats in Sausage Emulsions

There is an increasing recognition of the functionality, nutritive value and organoleptic advantages of processed plant proteins and fats when incorporated in comminuted meat products. However, legal implications in many countries greatly limit their extensive use. In Canada, although they may be used in hamburger type of meat, and meat loaves their use in sausage type products is prohibited. In the United States a maximum level between 2 and $3^{1}/_{2}$ per cent is permitted. As has been

previously discussed most of the processed plant proteins and fat utilizable in sausage type products are derived from soy bean and to a lesser extent from wheat gluten. Other potential sources include corn gluten, cotton seed and peanut protein isolates and hydrogenated fats. Soy protein products presently being used are high in good quality proteins for meat supplementation, some of them do possess both emulsification and binding properties and particularly in cooked sausages readily impart high moisture retaining propensities to the finished product.

Early work by Glabe et al in 1955 demonstrated the use of 'Gelsoy' in a sausage type product. In their experiment, a formulated meat composition was trimmed of all its visible fat, mixed with cure, processed into sausage emulsion of gelsoy and stuffed into visking casing. These were cooked through a temperature-time schedule, cooled for sixteen hours at $40^{\circ}F$ and then compared for the degree of free water and/or fat on the surface casing and deposited in pockets within the sausages. Results from their investigation indicated that gelsoy at both 0.5 per cent and 1 per cent levels increased the fat and water binding within the sausage. There was thus a concomitant increase in yield of the finished product which was found superior to that of skim milk used as binder.

Frank and Circle in 1959 reported the production of a frankfurter type simulated sausage using a water-insoluble soy protein preparation and an all vegetable shortening. The edible soy protein was dispersed in a trisodium phosphate solution, and mixed with fat, emulsifier, hydrolized vegetable protein seasoning, spices, smoke flavor and color to form an emulsion. This was stuffed into cellulose casing, linked and pressure cooked. Results of their evaluation indicated that fine ground protein isolates possessed the best binding capacity. They also observed an optimum moisture-protein ratio of 3.0 to 3.5 in the finished product and a pH range of 6.2 to 6.5 for acceptable texture. Steam cooking at 10 to 15 p.s.i.g. for about ten minutes was preferable to boiling in water as extensive leaching of color and flavor generally occurred in the latter. Although the presence of some fat was found to improve palatability, fat content could be varied between 4.5 per cent and 16 per cent.

In 1963, Swift Chemical Company marketed the Swift's Food Protein, a product containing 70 per cent protein. From sausage emulsion standpoint, SFP was reported not only to increase the protein level but also to absorb the fat and moisture as well as bind the mass as emulsion in the chopper. Gelatinization of the fortified sausage emulsion was also reported to occur at lower temperatures

resulting in products with excellent peelability although an internal temperature around 152°F was desirable.

Anonymous in 1966 described the attributes of 'Promine-C', 'Promine-D', 'Promine-K' and certain isolates which are believed to possess juice-retaining and fat dispersing capacities as well as being capable of achieving better product yield and reduced smoke house shrinkage.

Various workers have attempted to elucidate the effect of various plant proteins and fats on emulsion formation either in sausage type products or in model systems (Pearson et al 1965, Ronget and Bratzler 1966, Christian and Saffle 1967 and Inklaar and Fortuin 1969).

In 1965, Pearson et al carried out a comparative study on the emulsifying capacity and emulsion stabilizing properties of some proteins that are frequently added to sausages, particularly of soy sodium proteinate ('Promine-D'), potassium caseinate and non fat dry milk. For each additive, solutions containing various levels of protein nitrogen were mixed in a lightning stirrer with progressive addition of soy bean oil at a known rate until emulsion breakdown was observed as shown by a sudden drop in viscosity. The residual nitrogen in the aqueous layer separated on centrifugation was assayed to determine the amount of protein not involved in the interfacial reaction. The results from their investigation indicated that the greatest

emulsifying capacity for soy sodium proteinate was exhibited at a pH of 10.7 and an ionic strength of 0.5 followed by that at a pH of 6.9. Although at pH of 5.3, near that for meat, emulsification was reduced, its excellent binding characteristic made it an effective protein additive for comminuted meat.

Rongey and Bratzler in 1966 evaluated the effect of some binders on the palatability and processing characteristics of bologna. A basic composition was conventionally processed to contain 10 per cent of either non-fat dry milk or soya grit and evaluated for various parameters. Their findings indicated a higher storage shrink when soya grit, but not NFDM was used as binder. Soya grits also imparted a yellow color to the normally red bologna and a reduction in the measured tensile strength. It also elicited a negative preference scores during taste panel evaluation.

Comparative studies on the emulsification of plant and animal fats, and fatty acids by muscle salt-soluble protein were carried out in 1967 by Christian and Saffle using a modified procedure of Carpenter and Saffle (1964). Their result indicated that the emulsifying capacity decreased in the order of oleic,linoleic, myristic and palmitic acids when muscle salt-soluble protein was used as the emulsifier. They also reported that in a model

system more triglycerides can be emulsified than the corresponding free fatty acids.

Recently, Inklaar and Fortuin (1969) using a sausage formulation containing 'Promine-D', promosoy, sodium caseinate and an isolated soy protein (IPSO) demonstrated that with a given amount of water and oil, increasing the level of protein increased the stability of the sausage emulsion. They further determined that the water soluble protein content of an isolated soy protein may be used as a good indication of its use as an emulsion stabilizer.

Maturity and Dehydration of Sausage Products

Apart from the beneficial effects of smoking, antiseptic and germicidal effects, color development, antioxidant effect and gloss effect, the characteristic effect of the smoking process which results in a net loss of moisture from the smoked product is well recognized. Under prolonged smoking at elevated temperatures, this process is expedited but confined to the surface layers in which rapid denaturation of the proteins occur. The layer becoming very rigid, will crack under the strain of the internal pressure due to the imprisoned hot vapor in the interior. With cold smoking which sometimes extends over several hours, dehydration is longer and relatively more even. Heavy smoking even at low temperatures, if prolonged, results in the deposition of a glossy resinous material on the

sausage. This may sometimesact as a deterrent to dehydration.

In commercial practices, dry sausages are light cold smoked for an extended period or hot smoked for a few hours and then aged at temperatures about 15°F or lower for several days under about 60 per cent relative humidity. The rate of drying will depend upon such factors as the relative humidity, cold room temperature, rate of air exchange, extent of smoking, level of initial moisture content and lastly the size of the sausage. The latter factor is of importance as it controls the thickness of the material through which moisture must pass at the last stages of dehydration (Van Arsdel 1963).

Other associative changes occuring during the maturing process of sausages are chemical in nature. Both increase and decrease in the water-soluble proteins have been observed to occur in dry sausages depending on the condition under which the sausages were matured. A decrease in myosin, myogene and myoalbumin but not the collagen nor elastin content of dry sausages were observed in 1962 by Pezacki and Duda. They also reported an inhibitory effect on the hydrolysis of proteins during the later stages of ripening.

In their experiment of 1967, Milhalyi and Kormendy investigated the changes in protein solubility and associated properties during the ripening of Hungarian dry sausages. Their results indicated a rapid decrease in moisture content coupled with an increase in salt content which however had no inhibitory effect on protein hydrolysis probably due to enzyme activity of the bacterial enzymes. Increasing changes in fat acidity with ripening time also suggested the presence of lipolytic organisms. Generally, rapid drying in the outer zone affected protein denaturation.

Depending on the degree of dryness, moisture content in the dry sausages vary from about 20 per cent to around 40 per cent, the latter sausages requiring some degree of refrigeration for extended stability.

SCOPE OF INVESTIGATION

The scope of this investigation was to determine the effect of substituting various levels of meat protein and fat with equivalent levels of processed vegetable protein and fat on certain parameters in a semi-dried (Pepperoni) sausage type product. Such a product which would require practically no refrigeration could find a possible use in those areas of the world where there is a deficit in animal protein supply. Specifically, the following areas were investigated.

1. The effect of substituting various levels of the meat protein in a semi-dried sausage type product with equivalent levels of soy sodium proteinate 'PROMINE-D' on the colour, texture and organoleptic properties of the finished sausage.
2. The effect of substituting various levels of the meat fat in a semi-dried sausage type product with equivalent levels of 'Crisco' all-vegetable shortening on the colour, texture and organoleptic properties of the finished sausage.
3. The combined effect of simultaneously replacing various levels of meat protein and fat in a semi-dried sausage type product with equivalent levels of

'Promine-D' and 'Crisco' all-vegetable shortening on the colour, texture and organoleptic properties of the finished sausage.

MATERIALS AND METHODS

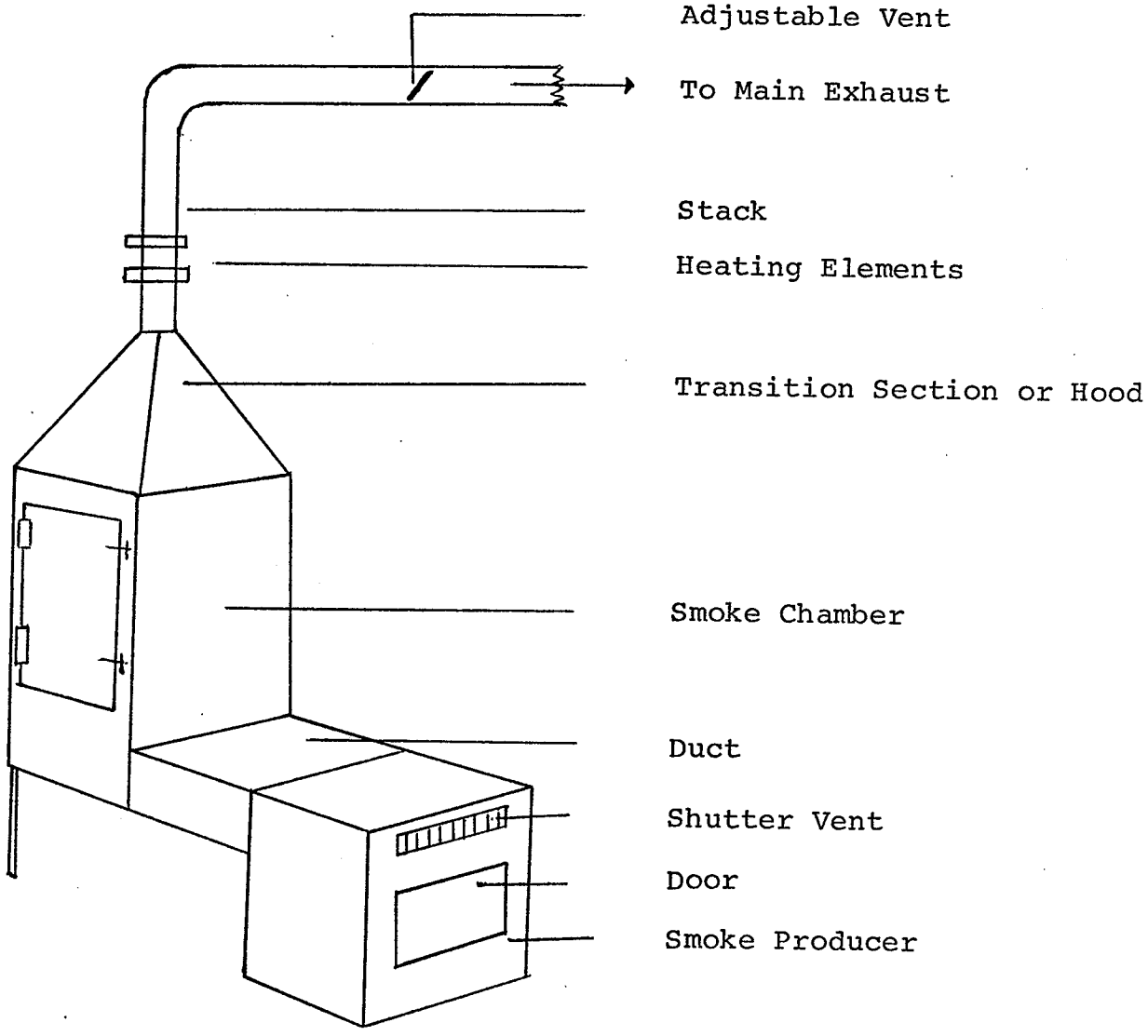
The Smoke House

The smoke house (Figure 2) utilised in this work was designed by Lantz (1969) and was slightly modified to suite the desired experimental conditions. The smoke house was constructed of galvanised sheet metal and consisted essentially of a smoke producer with two shutter vents and a door through which the wood chips were fed in, a smoke duct, a smoke chamber, a transition section or hood, and a stack which was connected to a main exhaust duct through which a forced draft was maintained. The smoke chamber had a door 2 feet 9 inches by 1 foot 6 inches through which the sausages were placed in the smoke house. On the two opposite side walls were each located two galvanised metal strips spaced 12 inches apart. These support ½ inch round metal rods from which the sausages were suspended.

An adjustable vent installed midway along the stack was used to control the rate of airflow through the smoke house. Two heating elements installed prior to the adjustable vent were used to generate temperatures around 550^{o}F to destroy any micro-organisms which might escape through the chimney during the smoking operation. The smoke generator, duct and smoke chamber were insulated with fibre glass to conserve and equalize heat distribution

Figure 2

THE SMOKE HOUSE



within the chamber. Whenever necessary, some metal sheets were conveniently deployed on a raised platform within the smoke chamber to modify the air flow pattern through the smoke house and thus eliminate possible cold spots.

Sources of Plant Proteins

Of the various types of purified and concentrated plant proteins available on the market two types were utilized in this investigation. 'Livelong V.P.', an all-vegetable protein food was extracted from wheat gluten. It is believed to possess organoleptic properties similar to those of minced meat and which it had been used to replace at levels up to 50 per cent in hamburger type meat patties. 'Promine-D', the second all-vegetable protein utilized in this investigation is a bland isolated soy protein (also known as sodium soy proteinate) prepared from defatted soy bean flakes which was obtained from high-quality, sound, clean, dehulled soy beans. It is a creamy-white finely divided powder which on dispersion in water would gel at a temperature close to 150^{o}F.

Source of All-Vegetable Fat

'Crisco' shortening, a class of fat of lardlike consistency was used as the source of the all-vegetable fat. This hydrogenated shortening prepared from a blend of palm oil and soy bean oil at freezing temperatures

formed a highly plastic material and at room temperature remained in a semi-solid state.

Meat Handling

Three types of meat - boneless beef chuck, beef plate and beef cheek - were used for the experiments. These were obtained from a local commercial packing house. The boneless beef chuck was obtained already frozen while the beef plate and beef cheek were still in the fresh chilled state. All samples were transferred from the packing house to the Food Science laboratory and split into roughly two pound lots, packed in baggies and assigned randomly to treatment groups as required. Where not immediately needed, the small sample lots were stored in a freezer chest maintained at a temperature of $10^{o}F$ until required. Prior to each experiment, frozen samples were partially thawed overnight in a cold room maintained at a temperature between $34^{o}F$ and $41^{o}F$. They were then processed and smoked.

Chemical Analysis

Chemical Analysis were carried out on all samples for moisture, fat and crude protein.

Moisture and Fat Determination

The moisture and fat contents of each raw emulsion and prepared sausage sample were determined simultaneously by a procedure which slightly modifies the SI-MO-FAT Method outlined by Davis et al (1966). Sausage samples passed through a small hand grinder for proper homogenization were observed to lose some fat through smears on the grinding equipment. To avoid this loss, samples were sliced with a thin knife, and the sliced portion well mixed. About 10 gms. of each sample was weighed exactly into a weighed 33 x 94 mm. cellulose extraction thimble capped with a swathe of cotton wool and reweighed. It was then transferred into a soxhlet extraction tube.

The extraction unit was composed of a 250 ml. Erlenmeyer flask, a soxhlet extraction tube, a Dean and Stark distillation receiver designed for use with the soxhlet extractor and a reflux condenser. Heat was supplied to the soxhlet extraction units through a rack of hot plates, heating tapes and simmerstat. The extraction unit was assembled and approximately 150 mls. of Di-n-butyl ether added to cover the sample before starting the extraction. This solvent forms an

azeotrope with water and boils at 94.1°C with a composition containing 33.4 per cent water (Hodgman et al, 1963). The soxhlet tube and distillation receiver arm were then insulated with double layered aluminium foil. Refluxing distillation in the extraction tube was maintained with a heating tape while the lower flask was heated with a hot plate. The extraction was completed in two hours after which the heating was terminated. The unit was allowed to cool and the volume of separated water in the distillation receiver taken as the moisture content in the sample.

The thimble was drained and placed in a vacuum oven which was preheated to a temperature of 150°C. It was then desolvented completely under vacuum at 28 inches of mercury for about 30 minutes. A glass trap placed between the oven and the pump and which was bathed in an antifreeze containing dry ice enabled the recovery of the solvent. Later, it was observed that trace amount of the solvent were escaping the trapping system. The possible effect of this on the vacuum pump coupled with the fact that the recovery of the used solvent was no longer essential, necessitated yet another modification of the process of desolventation. Following the extraction of both moisture and fat,the thimbles were drained and left in a fume cupboard overnight to vapourise the bulk of the solvent.

The partially dried thimbles were then completely dried as previously outlined in the vacuum oven for about 15 minutes or until the solvent odor could no longer be perceived when the oven was opened. The dried thimbles were then transferred to a dessicator to cool. Each cooled thimble was rapidly weighed because of the tendency of the dried samples to absorb moisture. The weighed thimbles were returned immediately to the dessicator for later analysis for crude protein. The weight of each dried defatted sample as well as the fat content of the original sample was calculated by difference.

Crude Protein Determination

The crude protein content of each sausage samples was determined by the Improved Kjeldahl Procedure. Approximately 0.5 gm. of the dehydrated and defatted residue from the moisture and fat determination was weighed rapidly into an 800 ml. pyrex round bottom flask. One Kel-Pak containing 0.7 gm. Mercuric Oxide and 10 gm. of powdered Potassium Sulfate was dropped into the same flask. The flask neck was washed down with a few mls. of carbon dioxide free distilled water and 25 mls. of concentrated sulfuric acid added. The flask was digested over a heating element for about forty minutes with its opening inserted in an exhaust intake. It was then cooled for

fifteen minutes or until white crystals of calcium sulfate could just be seen in the digested solution. 250 mls. of cold tap water was added and the contents well mixed. 80 mls. of standard 0.1060 N hydrochloric acid and three drops of 0.5 per cent alcoholic methyl red indicator were transferred into a 500 ml. Erlenmeyer flask and placed under the distilling tube. 25 mls. of 1.0126N sodium thiosulfate solution and a few zinc granules were added to the digestion flask and its contents well mixed. 50 mls. of concentrated sodium hydroxide were transferred carefully into the digestion flask to form a layer and the flask was immediately connected tightly to the distillation bulb on the condenser the tip of which was immersed in the acid in the receiver. The distillation flask was rapidly agitated and heated until at least 150 mls. of its content had distilled over into the receiver. This was then lowered to prevent back syphoning and to allow proper drainage from the distilling tube. The solution was allowed to cool and then titrated with a standard 0.0571 sodium hydroxide solution to a golden yellow endpoint. The titre was corrected for blank determination and the nitrogen content computed. The crude protein in the dehydrated and defatted sample was determined using a factor of 6.25. This result was then utilized in determining the crude protein content on a wet weight basis.

Physical Determinations

In order to estimate the effects of the various treatments on the physical characteristics of the prepared sausages, two physical estimations were carried out, to evaluate changes in the color and texture of these sausages.

Color Measurement

Changes in the total color lightness, redness and yellowness were determined using a Hunter Lab Color Difference Meter Model D25. Just before each determination the instrument was standardised against a white standard tile calibrated in terms of Magnesium Oxide. Each sausage sample was sliced lengthwise into strips about $\frac{1}{2}$cm. thick. These were placed side-by-side, trimmed accordingly and fitted into a clear Hunter Lab standard cell. The color was then read by taking the L, a and b readings for lightness, redness and yellowness. For each set of readings, the readings for the all meat sample was taken as the reference standard and the color change for each treated sample was calculated by difference. The total color change was calculated using the expression:

$$\triangle e = \sqrt{(\triangle L)^2 + (\triangle a)^2 + (\triangle b)^2}$$

Objective Texture Measurement

The evaluation of changes in texture characteristics due to each specific treatment was achieved using an Allo Kramer Shear Press Model SP-12 IMP. This was fitted with a 5000 pound proving ring for use in conjunction with a standard shear-compression cell. Ten precision stainless steel blades which fitted on to the proving ring meshed with groves and shear bars in the sample cell box assembly.

A few sausage samples were cut to lengths of 7 cm. and shear-compressed in the standard cell, to determine the range switch setting appropriate for this determination. As a result, a 10 per cent setting for the freshly smoked sausages and a 20 per cent setting for the matured sausages were found to give the best recorder tracing. These settings were utilised in all subsequent determinations. The peak of each traced curve was read to determine the peak shear value.

Microbiological Determinations

In order to gauge a fair trend in the microbiological population of the sausage samples as a result of the processing procedure, a standard plate count and a yeast and mold count were carried out on all the raw ingredients and sausage samples at all major stages of production,

specifically, after the preparation of the raw emulsion, following smoking, maturing and after incubation at 37°C.

The standard plate count was determined by the approved procedure of the American Public Health Association. 11 gms. of the raw emulsion or sausage sample was transferred aseptically into a sterile blender cup and homogenised thoroughly with 99 mls. of sterile dilution blank. Further serial dilution was obtained by transferring 1 ml. from each successive dilution into alternate 99 mls. sterile blanks which were then vigorously agitated. An appropriate volume of each dilution was plated with a sterile melted standard methods agar and incubated for 48 hours at 32°C after which the number of viable colonies were determined. The yeast and mold counts were determined by the same procedure with the exception that the dilutions were plated with sterile melted potato dextrose agar. This was followed by an incubation period of 120 hours after which the viable colonies were determined.

In order to reduce contamination during processing to a minimum, all processing utensils were washed and sanitised with 200 ppm chlorine water before and after each treatment.

EXPERIMENTALS

1. Commercial Pepperoni Type Sausages

An evaluation of the chemical composition of four brands of commercial pepperoni type sausages was first carried out to determine the range of values characteristic of this type of product. Four brands of products were obtained from local grocery stores and analysed for moisture, fat and crude protein as previously outlined.

2. Operating Performance of Smoke House at Different Temperatures

To generate relatively constant temperatures during the smoking operation, the proper setting for both the upper and lower dampers on the smoke house were determined for temperatures of $90^{\circ}F$, $100^{\circ}F$, $120^{\circ}F$, $140^{\circ}F$ and $160^{\circ}F$ over a period of two hours. Temperatures were recorded using a Thermoelectric Multipoint Recorder. Smoke was generated by smouldering chipped birch wood.

3. Temperature Regime in a Conventional Smoke House

In order to evaluate the performance of the experimental smoke house with respect to the temperature regime during the smoking operation, similar determinations were made on a conventional smoke house during two different trials for comparison purposes. Temperature readings were taken with a Tele-thermometer (YSI Model 42SF).

4. Sausage Manufacture

Sausages prepared in this investigation were of the semi-dried pepperoni type. The formulation used is as outlined in Table 3 . Formulated weights of partially thawed meats and ice flakes were ground together with a Hobart meat grinder first through a ½ inch plate and then through a $^{3}/_{16}$ inch plate. The ground meat was transferred into a bowl chopper, where salt, pepperoni spice, praque powder and binder were added. It was partially mixed with a wooden ladle and then chopped for exactly one minute. The sausage emulsion was stuffed through a Dick sausage stuffer into a 21 mm. diameter collagen casing, tied at about four inch lengths and fitted on the smoking rods. The sausages were cured overnight at temperatures between 34°F and 41°F, then smoked for specified periods and time.

5. Sausage Samples Smoked at Different Temperatures

The effect of smoking for three hours at specific temperatures on the final internal temperature attained within smoked sausage samples, the surviving bacteria and yeast loads, as well as the moisture content of these samples were next investigated. Smoking was carried out at temperatures approximating 90°F, 100°F, 120°F, 140°F and 160°F respectively. All analyses were carried out as previously outlined.

Table 3

ALL MEAT SAUSAGE FORMULATION

Beef Chuck	453.6 grams
Beef Plate	272.16 "
Beef Cheek	181.14 "
Ice Flakes	90.72 "
Pepperoni Seasoning	18.14 "
Praque Powder ($NaNO_2$ + $NaNO_3$)	2.83 "
Salt	15.87 "
Binder	31.75 "

6. Variation in Added Water

As the desired sausage was to be a semi-dried type which would be relatively stable at ambient temperatures, it was necessary to reduce the moisture level of the finished product to lower than 30 per cent. As the initial level of moisture in the fresh product would greatly determine the ease of processing as well as the rate at which this level of moisture was to be achieved, a study was conducted to determine what minimum level of ice flakes could be incorporated during processing without jeopardizing the formation of a stable emulsion. The level of added ice flakes in the standard formulation was varied at levels of 0, 25, 50, 75 and 100 per cent. The smoked sausages were matured at 15°C in a Fisher Low Temperature Incubator for ten days. Moisture determination was carried out on the fresh emulsion, smoked and matured sausages for comparison.

7. 'Promine-D', 'Livelong V.P.' and 'Crisco' Shortening as Replacement for Beef Proteins and Fat

The effect of replacing meat proteins and fat with equivalent levels of 'Promine-D', 'Livelong V.P.' and an all-vegetable shortening were next investigated. The moisture, fat and crude protein contents of the beef chuck, beef plate and beef trimmings were determined as received. Weights of 'Promine-D' and 'Livelong V.P.' equivalent to the

total crude protein content of the meat were calculated. A similar calculation for vegetable shortening and beef fat was made. On this basis 65.5 grams of chuck lean containing 10 per cent of the protein in the total meat formulation was found equivalent to 17.42 grams of 'Livelong V.P'. and 15.18 grams of 'Promine-D'. For every 23.56 grams of plate fat constituting 10 per cent of the total fat content, 20.09 grams of 'Crisco' shortening was substituted. Substitutions of meat protein and fat using replacement levels of 0 per cent, 50 per cent, and 100 per cent of the vegetable proteins and fat were carried out as follows:

'Livelong V.P.'

a. 100 per cent animal protein and fat

b. 100 per cent animal fat, 50 per cent animal protein and 50 per cent 'Livelong V.P.'

c. 100 per cent vegetable fat, 50 per cent animal protein and 50 per cent 'Livelong V.P.'

d. 50 per cent each of animal protein, animal fat, 'Livelong V.P.' and shortening.

e. 100 per cent 'Livelong V.P.', 100 per cent animal fat.

f. 100 per cent 'Livelong V.P.', 100 per cent vegetable fat.

Similar substitution using appropriate weights of 'Promine-D' was made. Adjustment for the moisture content was carried out using the procedure outlined by Rongey et al (1966). The weight of the total meat removed was replaced by an equal weight of vegetable protein plus ice flakes.

For each combination, the basic process previously outlined for sausage manufacture was followed with a few modifications. 'Livelong V. P.' was presoaked for one hour in twice its weight of water at about 41°F and added with the other adjuncts to the ground meat in the silent cutter. 'Promine-D' was mixed with the other processing adjuncts in the dried state and transferred quantitatively to the ground meat and added ice flakes in the silent cutter. The prepared emulsion was stuffed into collagen casing, cured overnight and smoked as previously outlined. Smoked sausages were evaluated for gross characteristics and objectively for color differences.

8. Substitution of Meat Protein at Various Levels with 'Promine-D'.

The previous experiment established in part the gross undesirability of replacing meat protein and fat to any high level. Subsequent experiments were therefore limited to substitution levels ranging from nil to 50 per cent. In this phase of the investigations, the meat proteins were substituted with 'Promine-D' at six levels. starting from zero substitution, followed by a stepwise increment in substitution of 10 per cent protein to a maximum of 50 per cent. For all meat replacements, the calculated weights of meat lean were excised from the chuck portion, and equivalent weight of 'Promin-D plus

water was substituted following the procedure of Rongey et al (1966). In the all-meat sausage, the addition of ice flakes to the raw ingredients was deleted as results from experiment five (Appendix XII) established that the final moisture content of the matured sausages was preferable at zero level compared with the others. Adjustment in the levels of praque powder incorporated as the curing agent in each treatment was made to reflect the total change in the lean portion of the meat. Thus for each 65.5 grams of chuck lean removed, the praque powder content was reduced by 0.283 grams. The salt content was also reduced from 15.87 grams to 12 grams for replacement levels of 20 to 50 per cent inclusive to compensate for the apparent saltiness observed with progressive reduction in the lean portion of the meat.

As outlined on page 68, processing of the sausages was carried out in two pound lots of meat for each treatment (Table 3) 'Promine-D' was incorporated along with the spices. Five trials for each set of treatments were also carried out. Sausages were smoked for two hours at 90^{o}F after which the smoking temperature was raised to 160^{o}F for another one and a half hours to reach an internal temperature of not less than 140^{o}F. Both heat and smoke were generated by smouldering chipped wet birchwood in the

smoke generator. Smoked sausages were removed from the smoke house after three and a half hours, sprayed with very cold water and transferred to the cold room maintained at temperatures below 41°F where it was kept for a few hours. The smoked linked sausages were severed two to each portion, and hung in a Fisher Low Temperature Incubator maintained at 59°F. They were then matured for ten days.

Samples from all lots of fresh emulsions, smoked sausages and matured sausages were evaluated chemically for moisture, fat and crude proteins and microbiologically for total bacteria and yeast and mold counts. Matured sausages were further evaluated for colour, texture and sensory attributes as well as for keeping quality.

9. Substitution of Meat Fat at Various Levels with 'Crisco' All-Vegetable Shortening

The effects of substituting meat fat in the prepared sausage with 'Crisco' all-vegetable shortening at six levels from nil to fifty per cent on the chemical, physical and sensory attributes of the pepperoni type sausage was next investigated. The determination of equivalent levels of beef fat and 'Crisco' shortening was outlined in

experiment 7. All the fat substituted in all treatments was removed from the beef plate portion. The processing procedure was basically as outlined in experiment 8. The only differing feature was as follows: no adjustments were necessary for either the salt or praque powder contents listed in Table 3. To obtain a rather stable emulsion in most of the treatments, the weighed 'Crisco' shortening was frozen overnight at 10°F in which state it was slightly plastic and easily comminuted for uniform distribution throughout the batter. The shortening was added to the ground meat in the bowl of the silent cutter and first manually mixed with other processing adjuncts followed by emulsification for one minute. The stuffing, smoking and maturing were carried out as outline in experiment 8. Similar chemical, physical and organoleptic tests were also executed on samples from each treatment. Each set of treatments were carried out in five trials.

10. Substitution of Meat Protein and Fat Simultaneously With 'Promine-D' and 'Crisco' All-Vegetable Shortening

The combined effect of simultaneously substituting meat protein and fat with equivalent quantities of 'Promine-D' and 'Crisco' shortening at the six treatment levels were

determined using the basic procedure enunciated in experiments 8 and 9. The parameters measured were also the same as in these two experiments. Five trials for each set of treatments were also carried out.

Sensory Evaluations

In order to determine the relative acceptability of each of the six treated samples in each lot of the last three experiments, samples from each treated lot were subjected to a taste panel evaluation using the Hedonic Scale Scoring Test (Amerine et al 1965, and Larmond, 1967). The taste panel members were untrained although they were familiar with pepperoni sausage flavor attributes. Two sausages from each treatment in every lot were sliced in lengths of about one centimeter. Each length was further sliced into threee and together assigned randomly to one of eight judges. Scoring was carried out in the open laboratory. A cup of skimmed milk was provided for each judge for mouth rinsing after each tasting to counteract the hot flavor of the sausages. Panel members were also requested to rest a few seconds after each tasting to allow adequate recovery of the taste buds before tasting the next sample. Sample scores were evaluated by the factorial design method of analysis.

Evaluation for Keeping Quality

An accelerated procedure for evaluating the keeping qualities of the prepared sausages was used to estimate their relative stability under those conditions in which such sausages would normally be distributed. At exactly ten days maturity, one linked pair of sausage from each treatment was removed from the low temperature incubator and suspended in the open environment of an incubator maintained at a constant temperature of 37°C. After forty-eight hours, each sample was evaluated for total bacterial count and for yeast and mold count.

RESULTS

1. PRELIMINARY STUDIES

A. Commercial Pepperoni Type Sausages

In order to establish the range of values for the chemical composition of commercial pepperoni type sausages, it was necessary to analyse four brands of this type of sausage for moisture,fat and crude protein. The data presented in Table 4 demonstrated marked variability in the moisture, fat and crude protein contents of the four different brands. Fairly consistent results were obtained among the replicates for brands A and D. Variations among the replicates were obtained in brand B with respect to the fat content while brand C featured marked variation both in the moisture and fat contents. An average minimum moisture content of 22.37 per cent was observed in brand D while brand B featured a high average moisture content of 41.02 per cent. Similarly for the fat and crude protein contents of the four brands, a wide range in composition was evident.

B. Operating Performance of Smoke House at Different Temperatures

Data presented in Table 5 and Appendi es II, III, IV V and VI illustrated the temperatures attained within the smoke chamber when the upper and lower dampers of the smoke house were adjusted to positions determined during some trial smoking runs to attain five specific temperatures.

Table 4

COMPOSITION OF SOME COMMERCIAL PEPPERONI TYPE SAUSAGES*

Brand	Moisture %	Fat %	Crude Protein %
A	40.18	31.12	17.55
B	41.02	30.32	19.67
C	30.99	26.56	33.70
D	22.37	35.37	29.01

*Mean of five determinations (Appendix I)

Maintaining a fairly constant temperature within the chamber proved to be very difficult as at all desired temperatures, a wide range of temperature was observed among the five positions studied at the beginning of each experimental run. By varying the positions of both the upper and the lower dampers and when necessary, by appropriately positioning two movable dampers within the smoke chamber, equilibration of the temperature within the chamber at the desired level was attained within a reasonable range. At 90^{o}F, this range was minimised within the first twenty minutes and maintained at this level till the end of the two-hour smoking period. As the temperature within the chamber was increased, a slightly longer period was necessary to attain equilibration. At the higher temperature levels, the range was further magnified although the average temperature for the five points studied were close to the desired temperatures. To generate these higher temperatures, it was also necessary to reduce the blocking effect due to the upper damper. This was necessary to increase the air flow rate through the chamber as well as facilitate proper smouldering of the wood.

In a comparative study, the temperature regime within a typical controlled gas heated smoke house operated at about 160^{o}F was measured in two trials and at two different locations. Data presented in Table 6 indicated some degree of temperature fluctuation during the smoking process which was

Table 5

CHAMBER TEMPERATURE (^{o}F) AT FIVE EXPERIMENTAL SMOKING LEVELS*

Time in minutes	Desired Temperatures				
	90	100	120	140	160
0	117.6	133.6	122.8	120.4	101.4
10	100.8	123.2	100.4	179.6	108.2
20	95.0	109.4	138.8	103.2	142.6
30	95.0	108.0	120.2	162.0	137.6
40	90.8	103.0	130.8	147.8	160.0
50	90.0	102.2	122.2	137.0	160.0
60	90.0	100.0	124.0	134.2	166.0
70	90.0	101.2	123.6	145.0	154.2
80	90.0	100.0	121.6	141.0	156.0
90	90.0	100.0	120.0	139.8	158.0
100	88.6	98.8	118.6	138.2	158.0
110	87.6	96.0	119.4	140.2	172.0
120	88.0	95.2	120.0	138.4	153.6

*Mean of five readings, ref. Appendixes II to VI.

Table 6

TEMPERATURE PROFILE WITHIN A CONVENTIONAL SMOKE CHAMBER

Time in Minutes	Temperature Readings °F		Average
	1*	2**	
0	90	90	90
10	93	94	93.5
20	97	100	98.5
30	103	105	104.0
40	115	112	113.5
50	125	129	127.0
60	142	140	141.0
70	147	149	148.0
80	152	150	151.0
90	168	155	161.5
100	164	160	162.0
110	156	165	160.5
120	135	155	145
130	165	159	162
140	160	170	165
150	170	155	162.5
160	162	140	151
170	168	156	162
180	140	157	148.5

*Thermocouple attached to sausage rack but close to one sausage sample.

**Thermocouple placed close to middle section of smoke house.

comparable with those obtained in the experimental smoke house used in this work.

C. Sausages Smoked at Five Levels of Temperatures

The procedure outlined on page 68 for the preparation of fresh sausage emulsion proved satisfactory. As a first step in determining the temperature-time schedule for the experimental smoking operation, the effect of smoking for three hours at five temperature levels on the final internal temperature attained within the sausage samples, their moisture content as well as the lethality effect on the natural microflora present in the sausage samples were determined.

The data presented in Table 7 and Appendixes VII, VIII, IX, X and XI indicated that at all smoking temperatures, at no time did the internal temperature at the centre of the sausage sample reach the chamber temperature. The difference in the equilibration temperatures at these two points were lower at 90^{o}F smoking temperature and progressively increased with increasing chamber temperature. The rate of temperature rise at the sausage centre was also related to the temperature differential between those of the chamber and the interior of the sausage samples, being faster at the highest temperatures studied than at the lower temperature. An interior temperature of approximately 140^{o}F necessary to induce any appreciable lethality on the natural microflora of the sausage samples was achieved within fifty minutes when the smoking temperature was

Table 7

TEMPERATURES °F OF SMOKE CHAMBER AND MEAT SAUSAGE INTERIOR AT FIVE LEVELS OF SMOKING*

Time in Minutes	DESIRED TEMPERATURE °F									
	90		100		120		140		160	
	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.
0	79.6	33.4	102.6	38.2	114.0	38.6	86.4	35.2	163.8	41.6
10	92.0	63.4	107.4	71.0	103.8	64.2	120.6	67.6	152.2	86.6
20	100.2	69.4	100.2	76.4	121.4	74.8	126.0	79.6	158.6	113.8
30	88.4	70.6	101.0	77.8	114.8	87.8	108.4	82.0	156.0	117.2
40	93.8	72.2	101.8	79.4	131.6	98.2	133.8	90.6	157.2	121.0
50	97.6	74.8	102.6	80.6	126.4	99.0	135.4	95.4	174.8	132.4
60	92.2	77.4	104.4	81.4	124.4	101.0	135.0	104.0	168.8	139.6
70	91.4	78.4	104.2	82.6	126.0	102.4	134.8	110.0	162.8	140.8
80	92.8	80.6	103.0	83.4	124.6	106.8	148.8	112.0	146.6	137.2
90	90.8	79.8	111.6	86.4	123.0	113.0	158.2	116.0	152.6	138.0
100	90.8	80.6	101.6	89.4	119.8	110.4	144.8	127.6	149.6	138.2
110	90.8	80.4	101.6	91.2	126.2	110.0	134.0	128.0	156.0	138.6
120	89.8	81.4	101.6	92.6	129.4	109.2	133.6	125.4	167.0	139.8
130	90.6	82.0	103.4	94.4	134.2	114.4	133.6	122.8	159.6	139.4
140	90.0	82.2	103.2	95.0	126.4	110.4	136.4	123.6	167.0	140.8
150	87.0	82.2	106.0	93.0	120.2	108.6	137.2	125.0	165.2	141.4
160	88.6	82.8	105.0	92.8	120.8	109.6	142.6	127.2	166.4	141.8
170	89.0	83.4	103.8	93.2	115.8	109.6	141.6	126.6	159.4	140.2
180	89.6	83.2	103.0	93.6	116.8	109.6	141.8	127.0	158.4	140.0

*Mean of five trials, ref. Appendixes VII to XI

maintained around 160°F.

A dehydrating effect of the higher temperatures on the smoked sausage samples was observed as indicated in Table 8. This dehydrating effect was progressively reduced as the smoking temperature was lowered so that at 90°F the least dehydrating effect was observed with a corresponding loss of about 5 per cent of the moisture. On the other hand, at 160°F the dehydrating effect was maximised with a corresponding loss of about 9 per cent of the moisture. Intermediate temperatures of smoking elicited intermediate dehydrating responses.

With respect to the effect on the microflora of the sausage samples both the growth and lethality effects were featured at the different smoking temperatures studied as indicated in Table 9. An increase in the total bacterial count was observed at 90°F and to a larger extent at 100°F when bacteria growth was maximised, reaching a high of around 7 million per gram (Figure 3). The latter temperature is known to be the optimum growth temperature for the mesophylic group of bacteria. At the higher temperatures, the rate and extent of lethality were increased with increasing smoking temperatures. In three hours, smoking at 140°F reduced the bacteria flora to just below 20,000 colonies per gram while at 160°F for the same period, a further reduction to below 4,000 colonies per gram was achieved.

Table 8

THE EFFECT OF THREE HOUR SMOKING PERIOD AT VARIOUS TEMPERATURES ON THE MOISTURE CONTENT OF SMOKED MEAT SAUSAGES

Trials	TEMPERATURES °F									
	90		100		120		140		160	
	fresh	smoked	fresh	smoked	fresh	smoked	fresh	smoked	fresh	smoked
	%	%	%	%	%	%	%	%	%	%
1	64.06	59.79	64.16	59.35	64.07	59.98	64.95	57.14	64.05	59.85
2	65.16	59.62	64.38	60.70	64.19	58.04	64.23	58.38	64.63	57.93
3	63.00	62.39	63.72	59.40	64.59	58.27	64.82	60.57	64.48	58.24
Mean	64.07	60.60	64.09	59.82	64.28	58.76	64.67	58.70	64.39	58.67

Table 9

MICRO-FLORA OF RAW EMULSION AND SMOKED SAUSAGES AS AFFECTED BY SMOKING TEMPERATURES*

Smoking Temp. (°F)	Total Bacterial Count (Colonies Per Gram)		Yeast and Mold Count (Colonies Per Gram)	
	Raw	Smoked	Raw	Smoked
90	67.5×10^4	20.8×10^5	22.2×10^1	22.2×10^1
100	90.8×10^4	69.7×10^5	12.5×10^1	4.3×10^1
120	58.8×10^4	28.8×10^4	13.3×10^1	4.2×10^1
140	10.5×10^5	17.4×10^3	8.2×10^1	0.0×10^1
160	84.0×10^4	39.0×10^2	20.2×10^1	0.0×10^1

*Mean of three trials.

The effect due to the combined action of temperature and smoke appeared to be more drastic on the yeast and mold organisms as could be seen in Table 9. Smoking at 90°F appeared to have no net growth or lethality effect on these organisms, but increasing temperatures elicited a net lethality effect. At 140°F and 160°F smoking temperatures, all yeast and mold cells appeared to be completely eliminated (Figure 4).

Physical examination of sausage samples smoked at the different temperatures showed that sausages smoked at 90°F and 100°F were of a desirable golden brown color. With increase in the smoking temperatures, sausage samples were progressively darker in color. At 160°F the dark color formation was accompanied by the deposition of a slightly sticky dark resinous material from the smoke which rendered the smoked sausage samples slightly undesirable. It was therefore decided to combine the desirable features of both cold and hot smoking to achieve a thoroughly cooked but golden brown colored sausage. The subsequent smoking periods were therefore extended for thirty minutes to allow a smoking period of two hours at 90°F followed by a one and a half hour smoking period at 160°F. This smoking schedule proved satisfactory.

Figure 3

THE EFFECT OF SMOKING TEMPERATURE
ON BACTERIAL ORGANISMS IN MEAT SAUSAGE

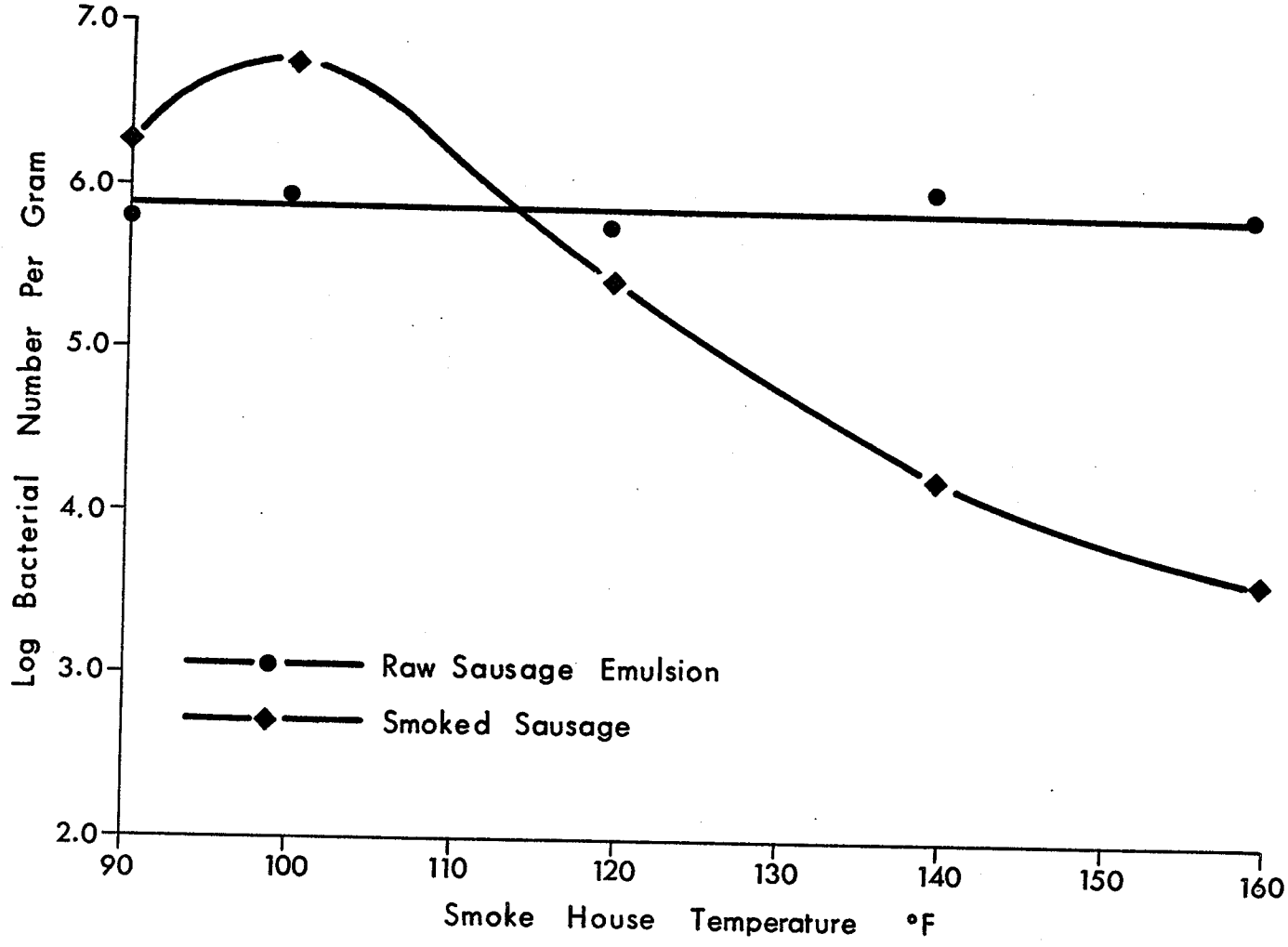
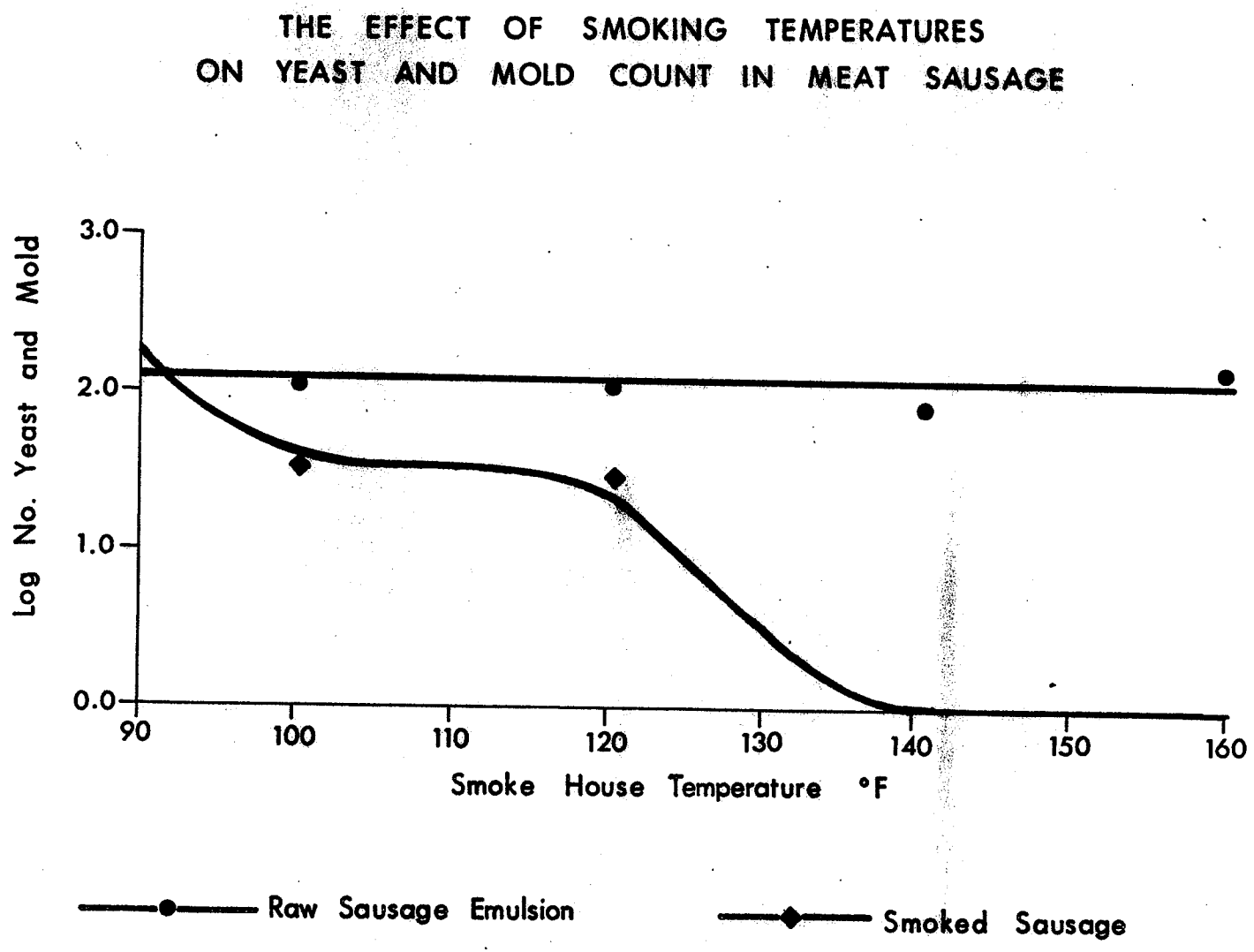


Figure 4


THE EFFECT OF SMOKING TEMPERATURES
ON YEAST AND MOLD COUNT IN MEAT SAUSAGE
Log No. Yeast and Mold
3.0
2.0
1.0
0.0
90
100
110
120
130
140
150
160
Smoke House Temperature °F
Raw Sausage Emulsion
Smoked Sausage

D. Variation in Level of Added Ice Flakes

The level of ice flakes added to the basic sausage formulation (Table 3) was varied in five stages to evaluate its effect on the moisture content of the matured sausage. Data presented in Table 10 and Appendix XII respectively, indicated that the level of added ice flakes during the chopping operation was reflected in the analysed moisture contents of the raw emulsion and in both smoked and matured sausages, but not to the same relative degree. As was expected, decreasing levels of added ice flakes resulted in decreasing levels of analysed moisture content. At all levels, the moisture content of the matured sausages was below 30 per cent and at zero level, the analysed moisture of 25.16 per cent indicated that a more stable dry sausage could be obtained when no ice flakes were added to the basic formulation. Because of this, no further added ice was incorporated in succeeding trials.

E. Replacement of Meat Proteins and Fat with 'Promine-D', 'Livelong V.P.' and 'Crisco' Shortening

Marked differences were observed in both the physical and visual characteristics of sausages in which meat proteins and fat were replaced by 'Promine-D', 'Livelong V.P.' and 'Crisco' shortening. In general, sausages in which higher levels of plant protein and fat were incorporated had a characteristic softer texture than those made from red meat

Table 10

THE EFFECT OF VARIOUS LEVELS OF ADDED FLAKED ICE ON THE MOISTURE CONTENT OF RAW, SMOKED AND MATURED SAUSAGES

	Percent Moisture*		
Level of added flaked ice (gms)	Raw Emulsion	Smoked Sausage	Matured Sausage
90.72	67.45	59.57	28.90
68.04	67.43	58.72	26.85
45.36	65.96	56.78	26.65
22.68	64.11	55.76	26.72
0.0	60.97	55.93	25.16

*Average of five determinations ref. Appendix XII.

and lacks "snap". Toughness increased as meat protein content increased. Conversely, texture became softer and poorer as the levels of shortening, 'Promine-D' and 'Livelong V.P.' were increased.

Sausages in which meat protein and fat were replaced as described by 'Livelong V.P.' and 'Crisco' shortening were illustrated in Figure 5. It could be readily observed that color deterioration increased with subsequent levels of substitution of both meat proteins and fat. This color deterioration is quantitated in Table 11 in which a progressive increase in color change could be deduced. Samples C, D, E and F generally assumed a rather pale color.

Texturewise, rapid deterioration was also discernible. The shear press values shown in Table 12 indicated that at 50 per cent level of substitution of both the meat protein and fat, rapid softening of the smoked sausages occurred. In appearance, these sausages were soft and mushy. The last three samples lacked both cohesiveness and adhesiveness while sample F appeared grainy. In fact sample F appeared to exhibit a state of an inverted emulsion in which the protein particles were enmeshed in a fat covering as distinct from a normal sausage emulsion in which the fat is enmeshed in a thin film of protein. Sausages with higher levels of 'Livelong V.P.' also possessed a characteristic obnoxious odor which made them undesirable.

Figure 5

REPLACEMENT OF MEAT PROTEIN AND FAT WITH 'LIVELONG V.P.' AND 'CRISCO' SHORTENING

A. 100 per cent meat protein and fat

B. 100 per cent meat fat, 50 per cent meat protein and 50 per cent 'Livelong V.P.'

C. 100 per cent vegetable fat, 50 per cent meat protein and 50 per cent 'Livelong V.P.'

D. 50 per cent each of meat protein, 'Livelong V.P.', meat fat and vegetable fat

E. 100 per cent 'Livelong V.P.' and 100 per cent meat fat

F. 100 per cent 'Livelong V.P.' and 100 per cent vegetable fat

Figure 5

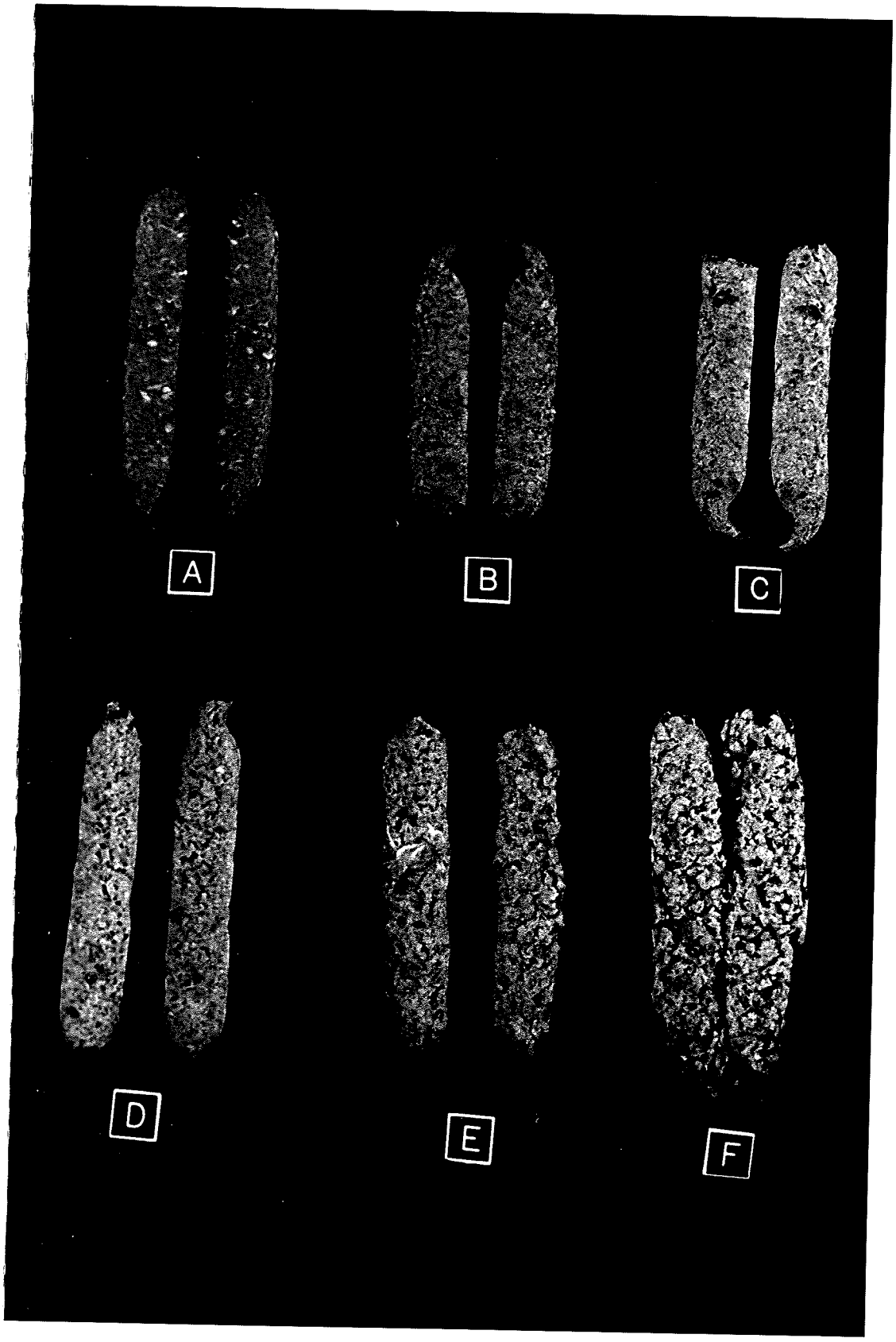


Table 11

COLOR CHANGE EXPRESSED AS Δ E AS AFFECTED BY THE SUBSTITUTION OF MEAT PROTEINS AND FAT WITH 'LIVELONG V.P.' AND VEGETABLE FAT IN SMOKED SAUSAGES*

	Samples				
Trials	B	C	D	E	F
1	4.44	5.06	5.76	9.43	9.5
2	5.85	5.56	6.80	10.59	11.34
3	5.55	5.66	6.89	9.64	10.52
Mean	5.28	5.43	6.48	9.89	10.45

*Sample A used as standard

Table 12

THE EFFECT OF SUBSTITUTING MEAT PROTEINS AND FAT 'LIVELONG V.P.' AND VEGETABLE FAT ON SHEAR PRESS VALUES OF SMOKED SAUSAGES

	Samples					
Trials	A	B	C	D	E	F
1	245	190	175	100	20	-
2	225	185	180	115	15	-
3	255	210	200	95	20	-
Mean	241.7	195	185	103.3	18.3	-

The substitution of meat protein and fat with 'Promine-D' and 'Crisco' shortening as described are featured in Figure 6. Similar color deterioration were featured with successive levels of substitutions, an increasing degree of lightness being very evident as can be seen in Table 13. Texture deterioration as demonstrated by the decreasing shear press values in Table 14 also paralleled decreasing meat protein and fat contents of the sausage samples. Like its 'Livelong V.P.' counterpart, sample F was extremely soft and mushy and failed to elicit any measurable response on the shear press scale. Obnoxious odor from the substituted samples was less marked.

As a result of the undesirable color and textural characteristics of all sausages at 50 per cent levels of substitution and below as well as the offensive odor of sausages in which 'Livelong V.P.' was used to substitute meat protein, all subsequent meat protein substitutions were carried out using 'Promine-D'.

2. 'PROMINE-D' AS REPLACEMENT FOR MEAT PROTEIN

The results from the latter part of the preliminary experiments indicated a gross deterioration in sausage color, texture and general qualities when meat protein was substituted at a level of 50 per cent and over. It was therefore decided to investigate what changes were brought about in the

Table 13

COLOR CHANGE EXPRESSED AS ΔE AS AFFECTED BY THE SUBSTITUTION OF MEAT PROTEINS AND FAT WITH 'PROMINE-D' AND VEGETABLE FAT IN SMOKED SAUSAGES

	Samples				
Trials	B	C	D	E	F
1	4.49	5.23	5.49	8.82	10.66
2	5.21	5.87	6.21	10.05	10.83
3	4.74	5.63	6.74	9.78	9.94
Mean	4.81	5.58	6.15	9.55	10.48

Table 14

THE EFFECT OF SUBSTITUTING MEAT PROTEIN AND FAT WITH 'PROMINE-D' AND VEGETABLE FAT ON SHEAR PRESS VALUES OF SMOKED SAUSAGES

	Samples					
Trials	A	B	C	D	E	F
1	235	175	160	90	15	-
2	275	215	160	85	15	-
3	205	185	145	100	10	-
Mean	238.3	191.7	153	91.6	13.3	-

Figure 6

REPLACEMENT OF MEAT PROTEIN AND FAT WITH 'PROMINE-D' AND 'CRISCO' SHORTENING

A. 100 per cent meat protein and fat

B. 100 per cent meat fat, 50 per cent meat protein and 50 per cent 'Promine-D'

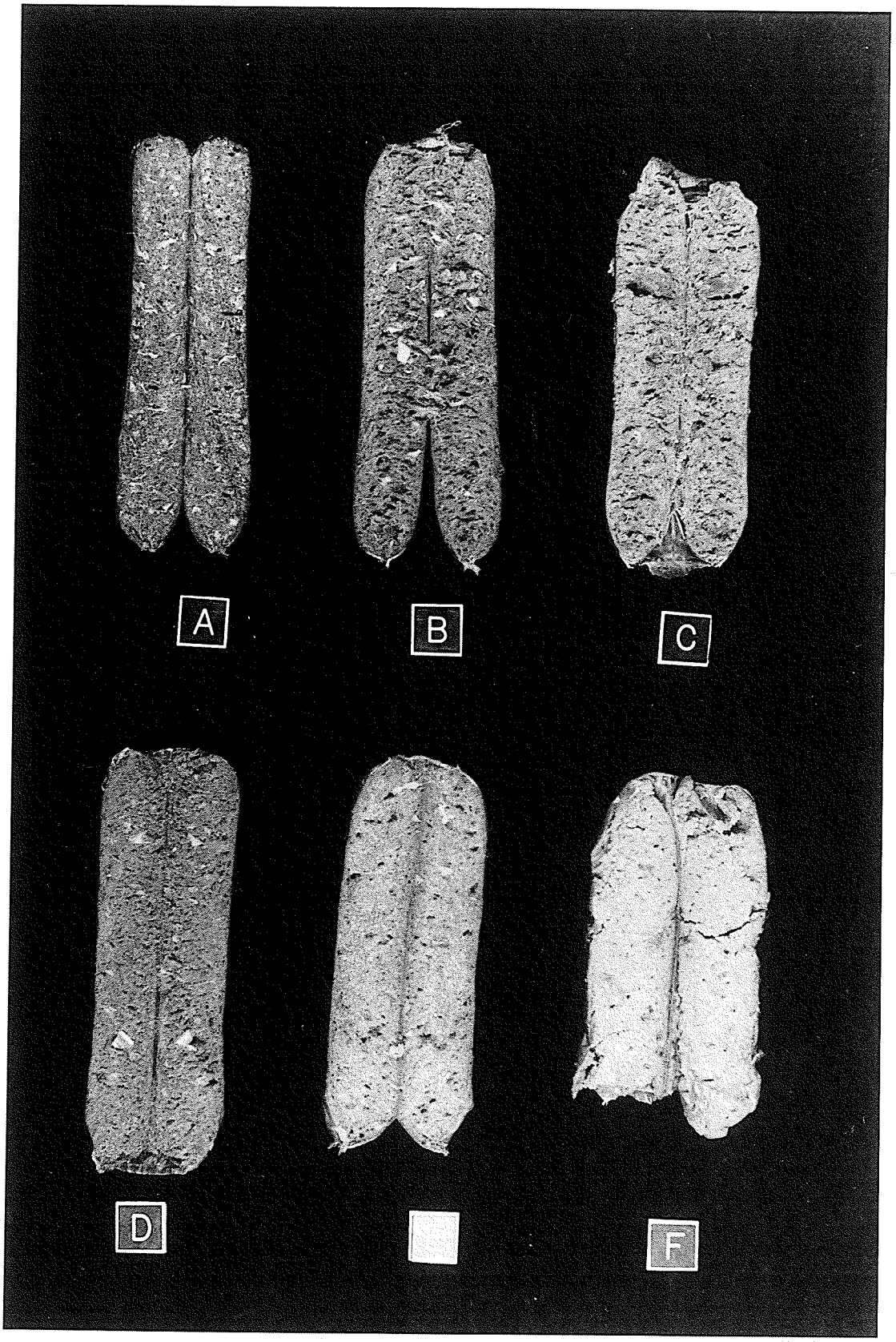
C. 100 per cent vegetable fat, 50 per cent meat protein and 50 per cent 'Promine-D'

D. 50 per cent each of meat protein, 'Promien-D', meat fat and vegetable fat

E. 100 per cent 'Promine-D' and 100 per cent meat fat

F. 100 per cent 'Promine-D' and 100 per cent vegetable fat

Figure 6



smoked and matured sausages when the meat proteins were replaced at levels between zero and 50 per cent inclusive. Meat proteins were therefore replaced by 'Promine-D' at levels of 0, 10, 20, 30, 40 and 50 per cent. Within limits, the procedure outlined by Rongey et al (1966) appeared to be reasonably satisfactory for substituting meat protein with 'Promine-D' and moisture. Chemical analysis of the prepared emulsion and smoked sausages in which meat protein was substituted at six levels are featured in Tables 15.

The sausage emulsion from the 0, 10 and 20 per cent levels of substitution appeared normal although at the 10 and 20 per cent levels a slight increase in apparent viscosity could be observed. Thereafter, decrease in apparent viscosity accompanied the increase in level of meat protein substituted. At the 50 per cent level of substitution, the prepared emulsion was of a softer consistency. The degree of color paling of the sausage emulsion also paralleled the increase in the level of 'Promine-D' incorporated.

A. Smoked Sausages

Except for a few isolated cases, the formation of fat caps, typical of poor formation of sausage emulsion was not observed in the smoked sausages at all levels of 'Promine-D' substitution. The physical characteristics of smoked sausages from the six levels of substitution could be seen in Figure 7. Both levels A and B exhibited uniform degrees of fineness

Table 15

COMPOSITION OF EMULSION, SMOKED AND MATURED SAUSAGES IN WHICH VARIOUS LEVELS OF MEAT PROTEINS ARE SUBSTITUTED WITH VEGETABLE PROTEIN AND FAT*

Product	PER CENT PROTEIN SUBSTITUTED																	
	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
Raw Emulsion	61.64	17.94	17.72	60.86	19.78	16.28	61.41	16.93	17.45	62.09	17.74	17.02	61.39	17.56	17.05	61.43	16.97	16.98
Smoked Sausage	60.04	14.74	17.01	58.88	17.11	16.70	59.95	15.52	16.63	60.69	15.05	16.61	58.87	16.08	17.11	58.96	15.99	17.02
Matured Sausage	26.13	27.10	32.06	25.09	29.98	31.00	22.15	28.15	32.49	24.54	29.08	32.27	23.14	30.6	30.87	23.12	27.49	32.10

*Mean of five trials, ref. Appendixes XIII, XIV and XV

Legend M = Moisture

F = Fat

CP = Crude Protein

Figure 7

THE EFFECT OF REPLACING MEAT PROTEIN WITH VARIOUS LEVELS OF VEGETABLE PROTEIN IN SMOKED SAUSAGES

A. 100 per cent meat protein

B. 90 per cent meat protein, 10 per cent vegetable protein

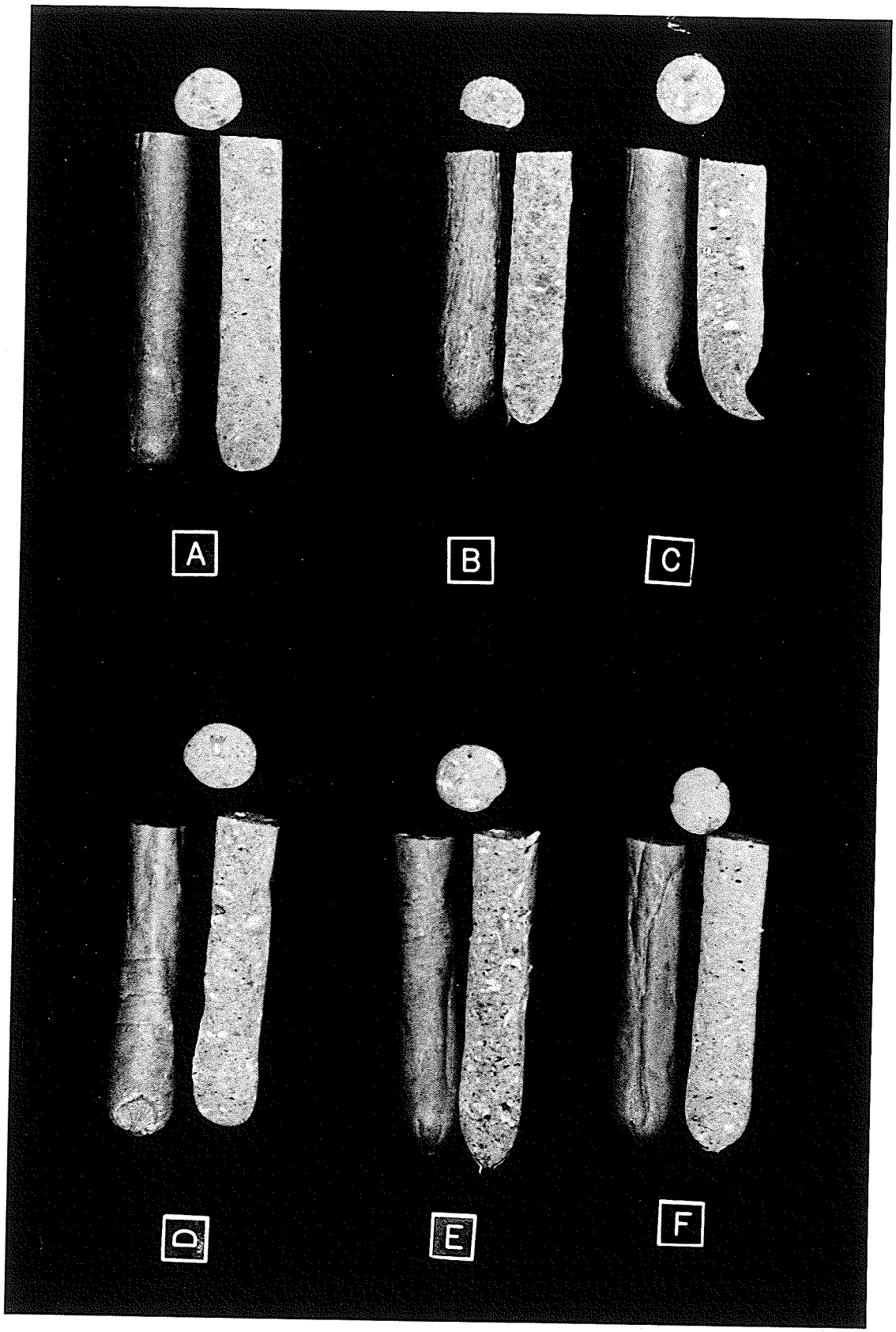
C. 80 per cent meat protein, 20 per cent vegetable protein

D. 70 per cent meat protein, 30 per cent vegetable protein

E. 60 per cent meat protein, 40 per cent vegetable protein

F. 50 per cent meat protein, 50 per cent vegetable protein

Figure 7



resulting from the chopping process. Beginning from level C, large particles of fibrous connective tissue became readily discernible as white fibres on the surface of the sliced samples. The meat particles also appeared coarsely ground. On the exterior surface of smoked samples E and F, a few heavy indentations were evident.

The effect on shear press values of smoked sausages of substituting meat protein with 'Promine-D' appeared to vary significantly with the level of substitution. As indicated in Table 16 and Figure 8, substitution at a level of 10 per cent of the meat protein induced a slight increase in the shear press value. However, further increase in the level of substitution resulted in progressively reduced shear press values indicating a lowering in the degree of toughness.

As indicated in Table 16, increasing levels of substitution elicited a diluting effect on the sausage color resulting in an increasing degree of color paling. Regression analysis indicated a high degree of correlation (96.58 per cent) between the ΔE values and the levels of protein substituted (Figure 9).

B. Matured Sausages

As indicated in Table 15, all matured samples on analysis contained below 30 per cent moisture indicating a good measure of dehydration. This dehydration was accompanied by a drastic increase in the degree of toughness as demonstrated in Figure 9. At all levels, the shear press values

Table 16

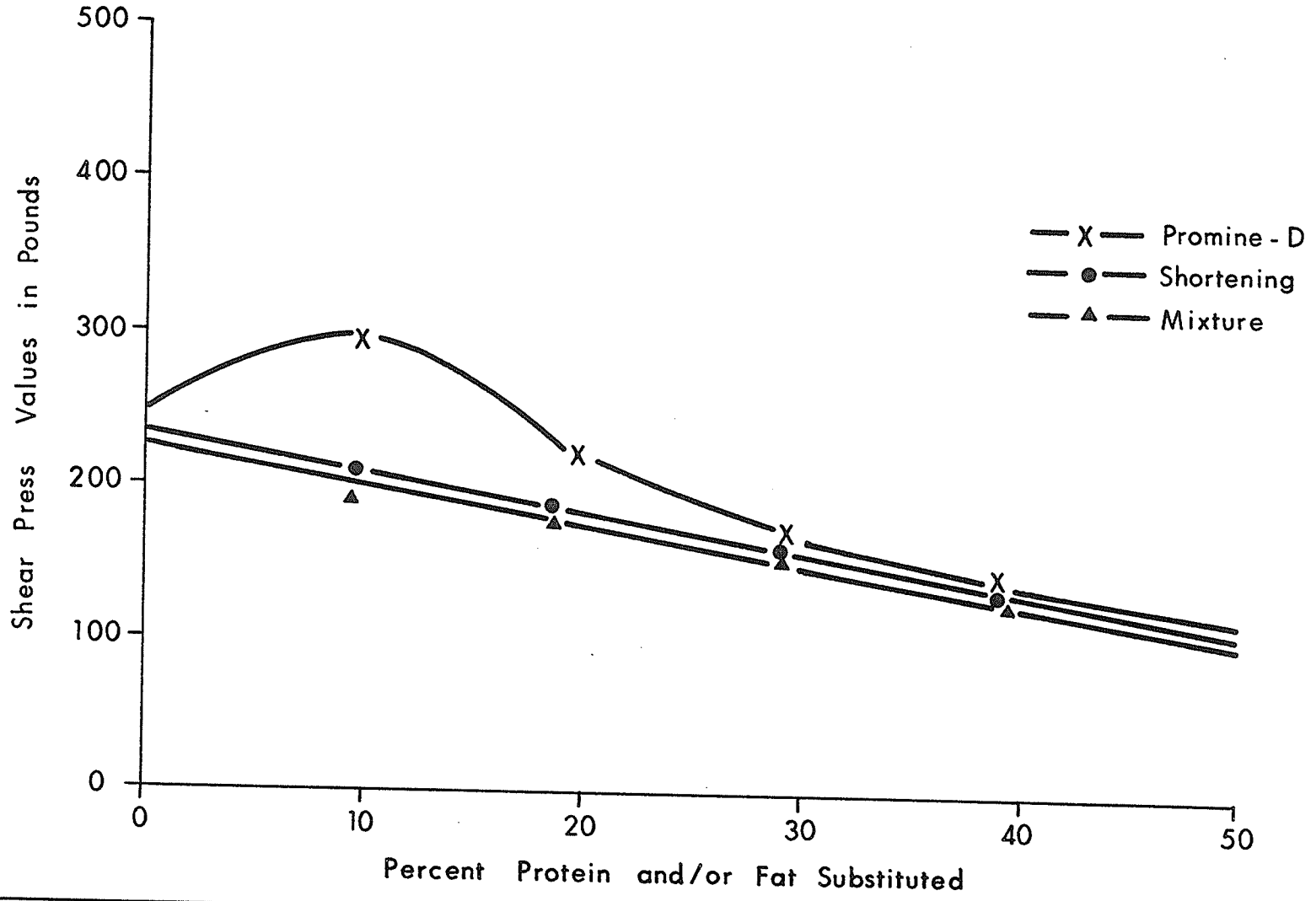
TOTAL COLOR CHANGE AND SHEAR PRESS VALUES OF SMOKED AND MATURED SAUSAGES IN WHICH VARIOUS LEVELS OF MEAT PROTEINS AND FAT ARE SUBSTITUTED WITH VEGETABLE PROTEIN AND FAT

Level of Substitution (%)	Color Change (ΔE)		Shear Press Values (lbs.)	
	Smoked	Matured	Smoked	Matured
0	-	-	242.0	419.8
10	1.05	2.07	221.0	412.0
20	3.14	1.14	194.0	376.4
30	4.17	1.48	158.0	317.4
40	5.37	1.87	133.0	193.2
50	6.12	3.49	106.0	182.2

*Mean of five trials

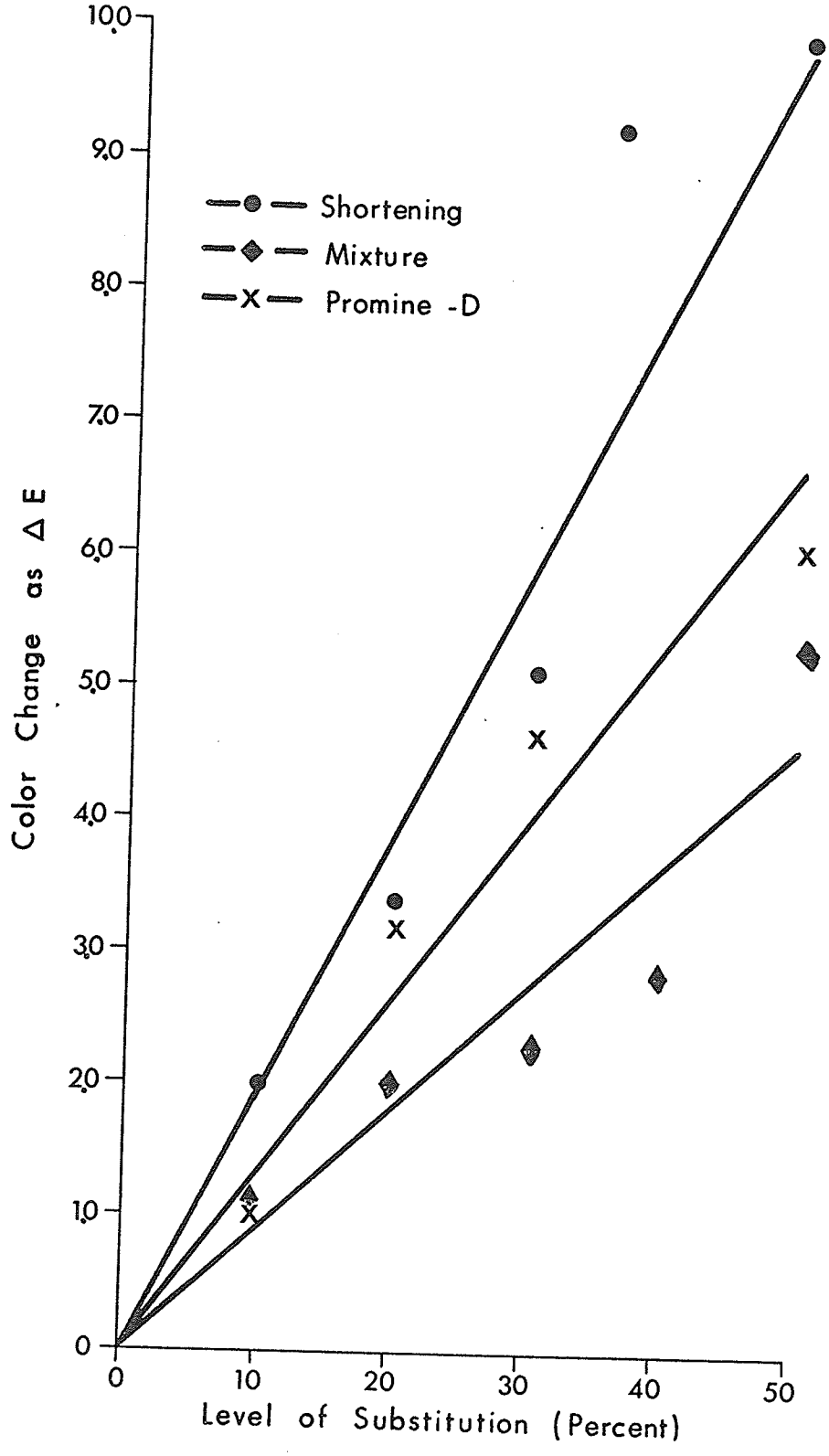
Figure 8

SHEAR PRESS VALUES OF SMOKED SAUSAGES
AS AFFECTED BY LEVELS OF PROTEIN
AND / OR FAT SUBSTITUTED



THE EFFECT OF SUBSTITUTING MEAT FAT AND PROTEINS ON SMOKED SAUSAGE COLOR

Figure 9



surpassed that of the all-meat protein sausage as indicated by the data presented in Table 16. The apparent change in shear press values was sigmoidal in character with the peak leveling attained at levels of substitution between 20 and 30 per cent. Decrease in shear press values beyond this point was almost linear to the 50 per cent level of substitution (Figure 10).

A linear relationship between Δ E values and level of protein substitution was also established as indicated by Table 16 and Figure 11. However, this relationship was of a lower order compared with the color change in the smoked sausages. Extensive darkening of the sausage color also occurred as evidenced in Figure 12.

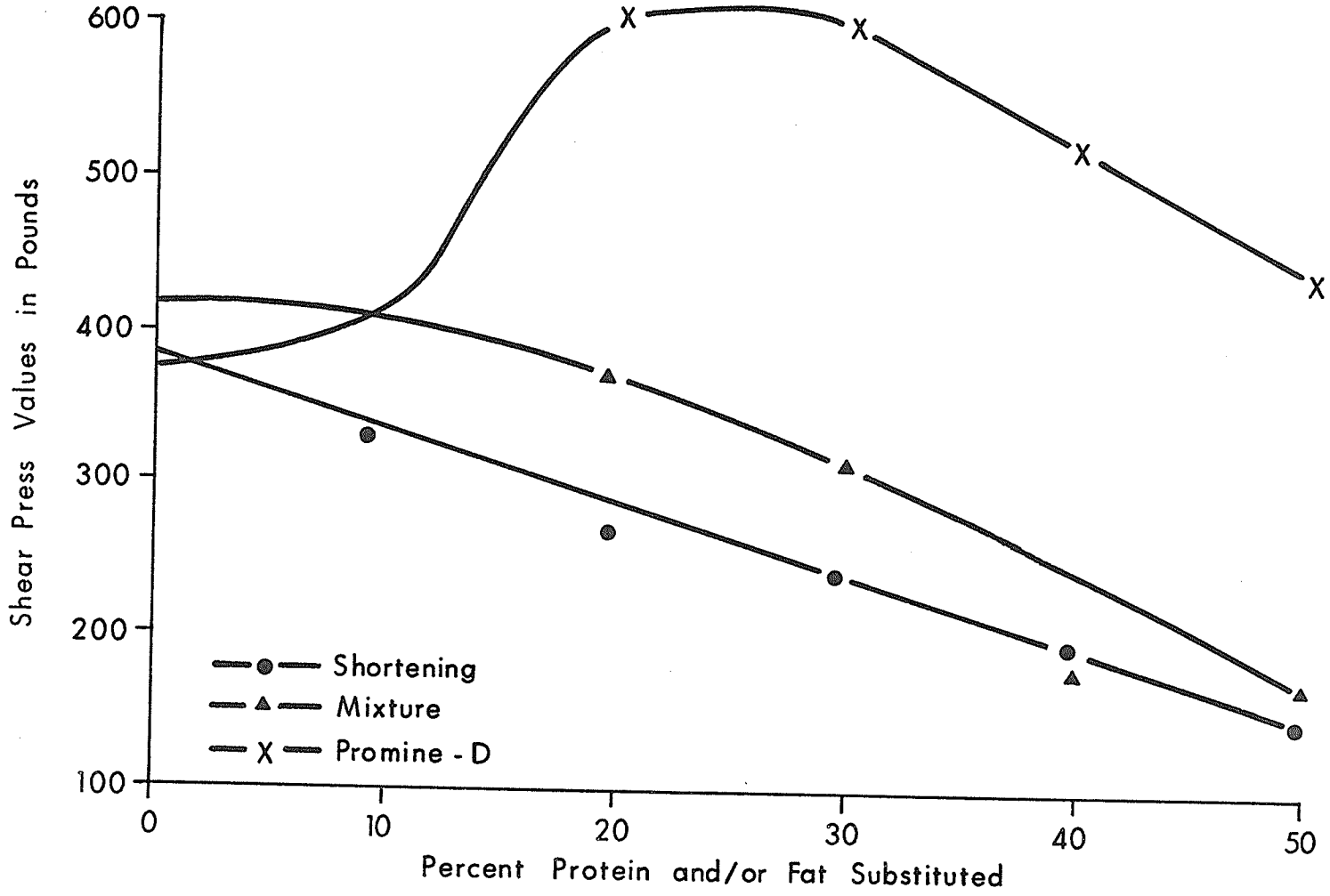
The physical characteristics of the matured sausages varied considerably from level to level. Sample A appeared to effect uniform shrinkage as the smooth outside surface would suggest. Increasing of the sausages with increasing levels of 'Promine-D' substitution appeared to suggest irregular shrinkage and possibly increasing case hardening. No fat weeping was observed among all the treatment levels.

C. Processing Effect on Microflora

The cumulative effect of smoking and hot temperature on the bacterial organism were of approximately the same order in all the six treatment levels. As shown in Table 17, the bacterial loads in all samples were reduced through two log

Figure 10

SHEAR PRESS VALUES OF MATURED SAUSAGES AS AFFECTED BY LEVEL OF PROTEIN AND / OR FAT SUBSTITUTED



THE EFFECT OF SUBSTITUTING MEAT FAT AND PROTEINS ON MATURED SAUSAGE COLOR

Figure 11

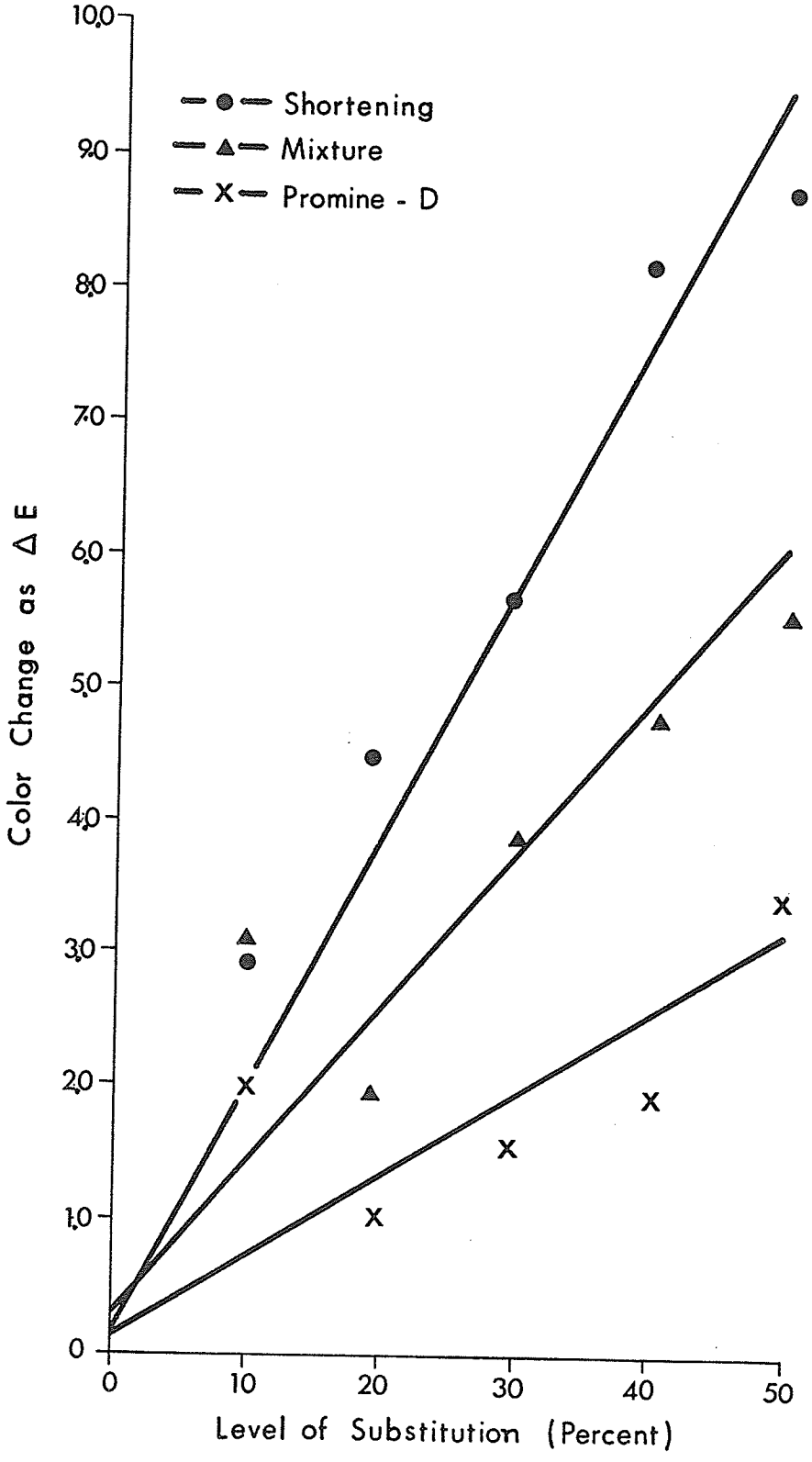


Figure 12

THE EFFECT OF REPLACING MEAT PROTEIN WITH VARIOUS LEVELS OF VEGETABLE PROTEIN IN MATURED SAUSAGES

A. 100 per cent meat protein

B. 90 per cent meat protein, 10 per cent vegetable protein

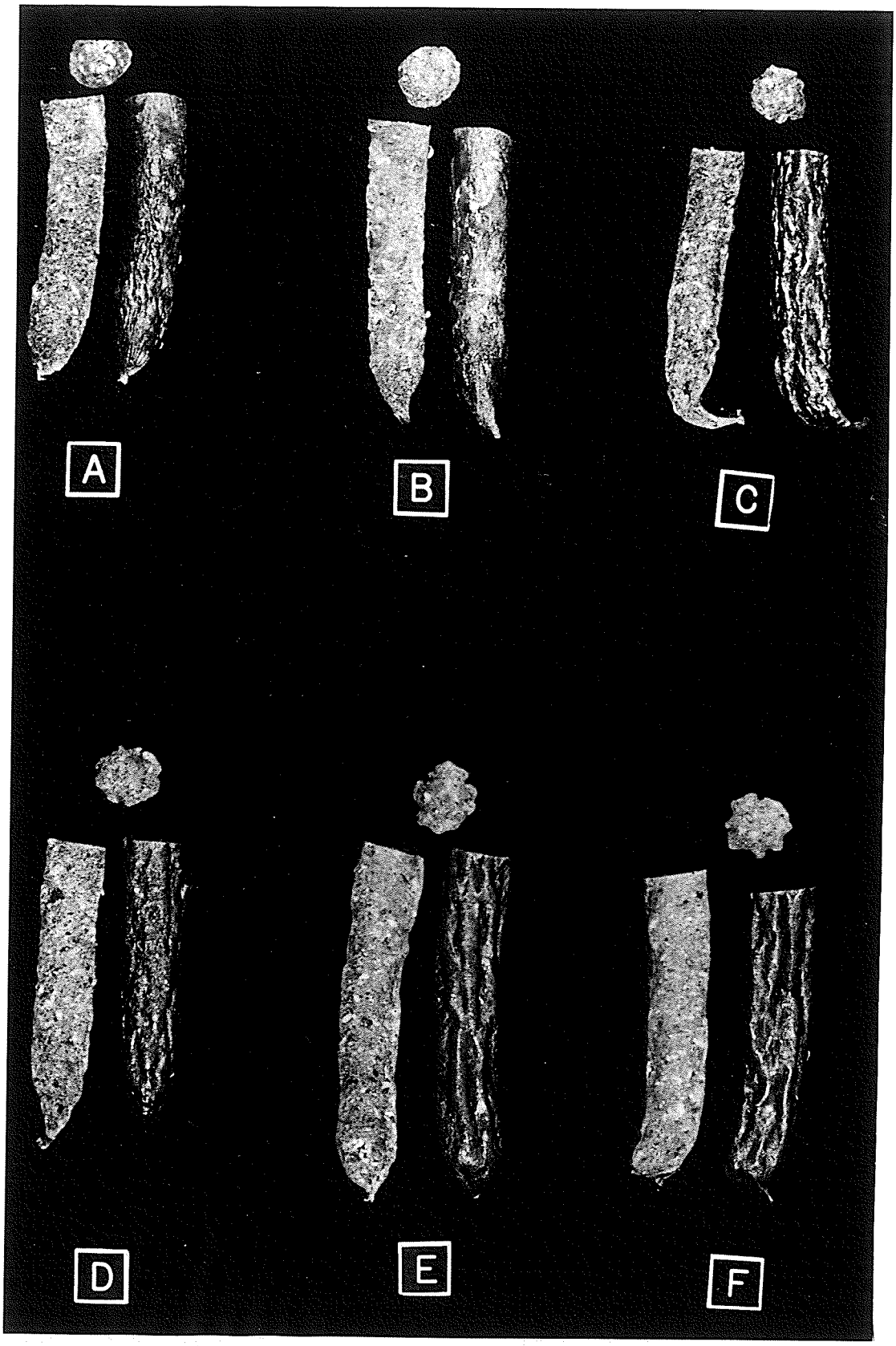
C. 80 per cent meat protein, 20 per cent vegetable protein

D. 70 per cent meat protein, 30 per cent vegetable protein

E. 60 per cent meat protein, 40 per cent vegetable protein

F. 50 per cent meat protein, 50 per cent vegetable protein

Figure 12



cycles to below 2,000 colonies per gram. Growth during ten days ripening period and during further incubation for forty-eight hours at 37°C was minimal. Lethality effect on yeast and mold colonies was drastic as shown in Table 18. No surviving cells were observed during maturation and the following incubation at 37°C.

3. 'CRISCO' SHORTENING AS REPLACEMENT FOR MEAT FAT

The chemical composition of the fresh emulsion and smoked sausage samples in which meat fat was replaced with vegetable fat are shown in Table 19. A slight but progressive decrease in the moisture content and a correspondingly slight increase in the fat content with increasing level of substitution of meat fat with vegetable fat appeared evident. This could be due to slight differences in moisture content of the meat fat and 'Crisco' shortening for which adjustments were not made in our calculations.

Effect of progressive substitution of the meat fat on the raw emulsion was less marked than that of the meat protein. However the emulsions were progressively lighter with higher levels of vegetable fat.

A. Smoked Sausages

A diminishing linear relationship appeared to occur between the levels of vegetable fat substituted and shear press values of the smoked sausages. As indicated in

Table 17

TOTAL BACTERIAL COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEINS SUBSTITUTED WITH VEGETABLE PROTEIN AS AFFECTED BY VARIOUS PROCESSING TREATMENTS*

Level of Protein Substituted (%)	Colonies Per Gram			
	After Chopping	After Smoking	After Maturity	After Incubation (37°C, 48 hours)
0	228.8×10^3	119.0×10^1	127.0×10^1	135.0×10^1
10	227.2×10^3	134.0×10^1	126.0×10^1	151.0×10^1
20	220.0×10^3	98.0×10^1	128.0×10^1	149.0×10^1
30	202.8×10^3	138.0×10^1	128.0×10^1	149.0×10^1
40	212.6×10^3	113.0×10^1	134.0×10^1	154.0×10^1
50	236.6×10^3	104.0×10^1	122.0×10^1	145.0×10^1

*Mean of five trials, ref. Appendix XXXVI

Table 18

YEAST AND MOLD COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEINS SUBSTITUTED WITH VEGETABLE PROTEIN AS AFFECTED BY VARIOUS PROCESSING TREATMENTS*

Level of Protein Substituted (%)	Colonies Per Gram			
	After Chopping	After Smoking	After Maturity	After Incubation (37°C, 48 hours)
0	251.0	0.0	0.0	0.0
10	235.0	0.0	0.0	0.0
20	250.0	0.0	0.0	0.0
30	216.0	0.0	0.0	0.0
40	262.0	0.0	0.0	0.0
50	279.0	0.0	0.0	0.0

*Mean of five trials, ref. Appendix XXXVII

Table 20 and Figure 8, the shear press value of the sausage was reduced to below half the average for the meat sausage sample at 50 per cent level of substitution. The increasing softness was readily observed at the 20 per cent level and above but not at the 10 per cent level as is obvious from Figure 13.

Color deterioration featured in Figures 9 and 13 was also extensive as vegetable fat replaced meat fat with a tendency towards increasing lightness. Regression analysis of Table 20 indicated a high degree of correlation between the levels of fat substituted and the ΔE values.

Fat cap formation was evident in many of the sausage samples particularly at the higher levels of substitution. The consistency of the sausages were also increasingly poorer.

B. Matured Sausages

As demonstrated in Table 19, the moisture contents of the matured sausages were considerably higher in most cases than their protein substituted counterpart featured in Table 15. This would suggest an interference in the rate of dehydration during maturation.

A gross reduction in sausage toughness relative to the level of fat substituted appeared to occur as featured by Table 20. This reduction was approximately linear. Again at the higher levels of substitution, sausage samples were

Table 19

COMPOSITION OF EMULSION, SMOKED AND MATURED SAUSAGES IN WHICH VARIOUS LEVELS OF MEAT FAT ARE SUBSTITUTED WITH VEGETABLE FAT*

Product	PER CENT FAT SUBSTITUTED																	
	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
Raw Emulsion	62.24	15.57	17.08	60.72	16.99	16.84	60.13	18.21	16.92	58.99	20.24	16.38	59.51	19.62	16.70	58.34	19.5	16.30
Smoked Sausage	57.73	15.85	17.04	58.83	15.82	17.05	57.22	15.74	17.56	56.42	17.08	17.73	57.59	17.29	16.92	58.69	16.92	17.01
Matured Sausage	27.79	26.44	30.61	26.56	28.74	31.11	28.50	31.24	29.62	30.58	28.73	29.32	32.96	30.37	28.20	31.41	29.64	28.98

*Mean of five trials, ref. Appendixes XVI, XVII and XVIII

Legend M = Moisture

F = Fat

CP = Crude Protein

Figure 13

THE EFFECT OF REPLACING MEAT FAT WITH VARIOUS LEVELS OF VEGETABLE FAT IN SMOKED SAUSAGES

A. 100 per cent meat fat

B. 90 per cent meat fat, 10 per cent vegetable fat

C. 80 per cent meat fat, 20 per cent vegetable fat

D. 70 per cent meat fat, 30 per cent vegetable fat

E. 60 per cent meat fat, 40 per cent vegetable fat

F. 50 per cent meat fat, 50 per cent vegetable fat

Figure 13

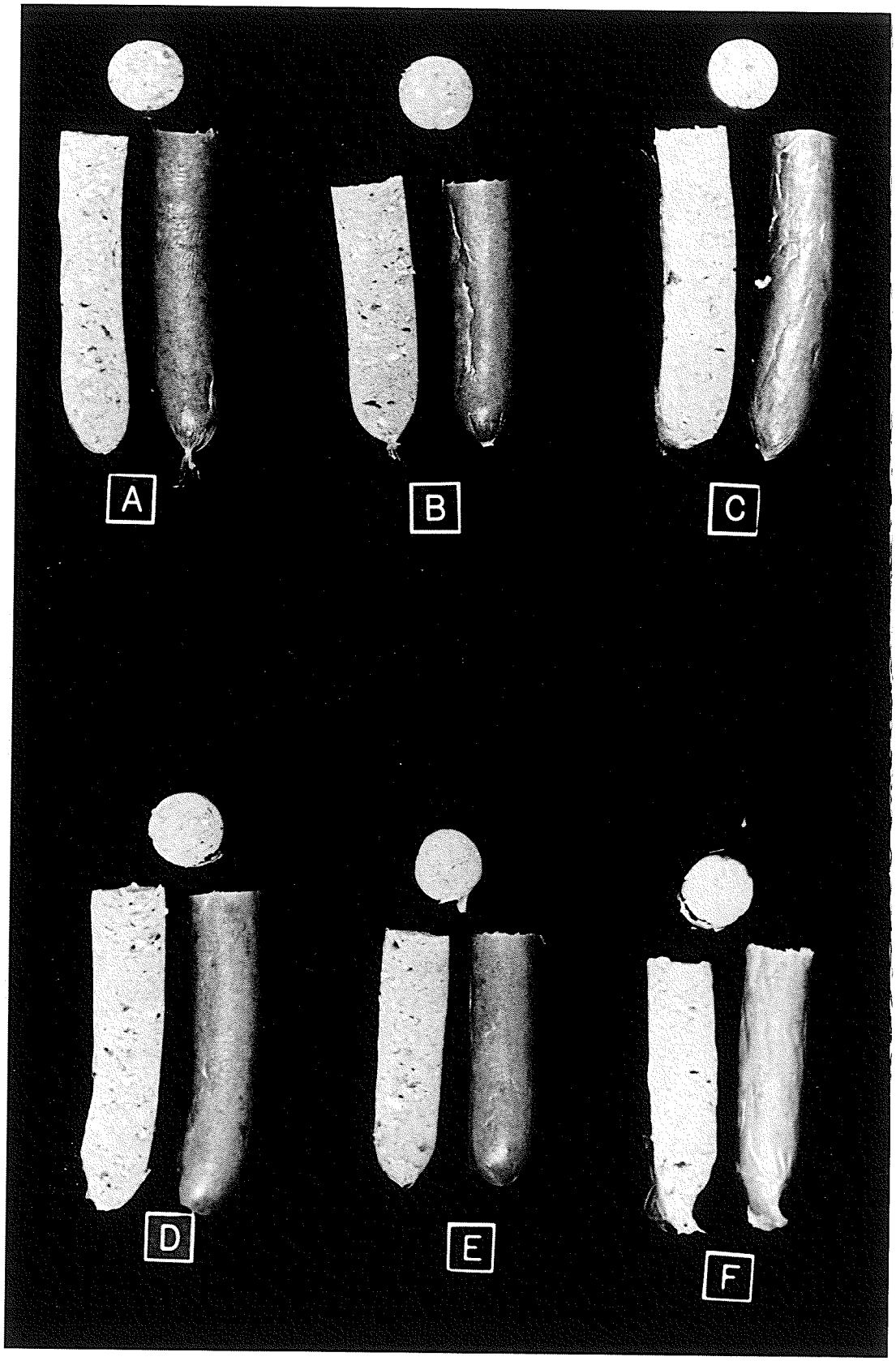


Table 20

TOTAL COLOR CHANGE AND SHEAR PRESS VALUES OF SMOKED AND MATURED SAUSAGES IN WHICH VARIOUS LEVELS OF MEAT ARE SUBSTITUTED WITH VEGETABLE FAT*

Level of Substitution (%)	Color Change (Δ E)		Shear Press Values (lbs.)	
	Smoked	Matured	Smoked	Matured
0	-	-	248.0	378.0
10	1.85	2.89	226.4	328.4
20	3.30	4.35	195.0	272.0
30	5.21	5.53	176.0	246.2
40	9.27	8.21	134.0	202.8
50	9.97	8.50	109.0	180.0

*Mean of five trials

characterised by an increasing softness and mushiness and the absence of desirable 'snap'.

The effect on sausage color was approximately of the same order as those of the smoked sausages. However, the matured sausage color was darker in all cases than was observed in the smoked sausages. Except in the first two levels of treatment, the apparent contractility which normally accompanied the dehydration was not obvious as can be seen in Figure 14. This could be related to the level of residual moisture in the matured sausages (Table 19). Fat sweating was exhibited by many of the matured sausages to higher degrees with increasing levels of fat substitution. This feature enhanced an oily characteristic which was readily discernible during taste panel evaluations.

C. Processing Effect on Microflora

Significant differences were not established on the cumulative effect of the hot temperature smoking on the microflora of the six levels of treatment. The lethality effects observed in Tables 21 and 22 were of the same order as was earlier determined in Tables 17 and 18.

4. SIMULTANEOUS REPLACEMENT OF MEAT PROTEIN AND FAT WITH VEGETABLE PROTEIN AND FAT

The chemical composition of both the raw emulsion and smoked sausages in which both the meat protein and fat were simultaneously replaced by 'Promine-D' and 'Crisco' shortening

Figure 14

THE EFFECT OF REPLACING MEAT FAT WITH VARIOUS LEVELS OF VEGETABLE FAT IN MATURED SAUSAGES

A. 100 per cent meat fat

B. 90 per cent meat fat, 10 per cent vegetable fat

C. 80 per cent meat fat, 20 per cent vegetable fat

D. 70 per cent meat fat, 30 per cent vegetable fat

E. 60 per cent meat fat, 40 per cent vegetable fat

F. 50 per cent meat fat, 50 per cent vegetable fat

Figure 14

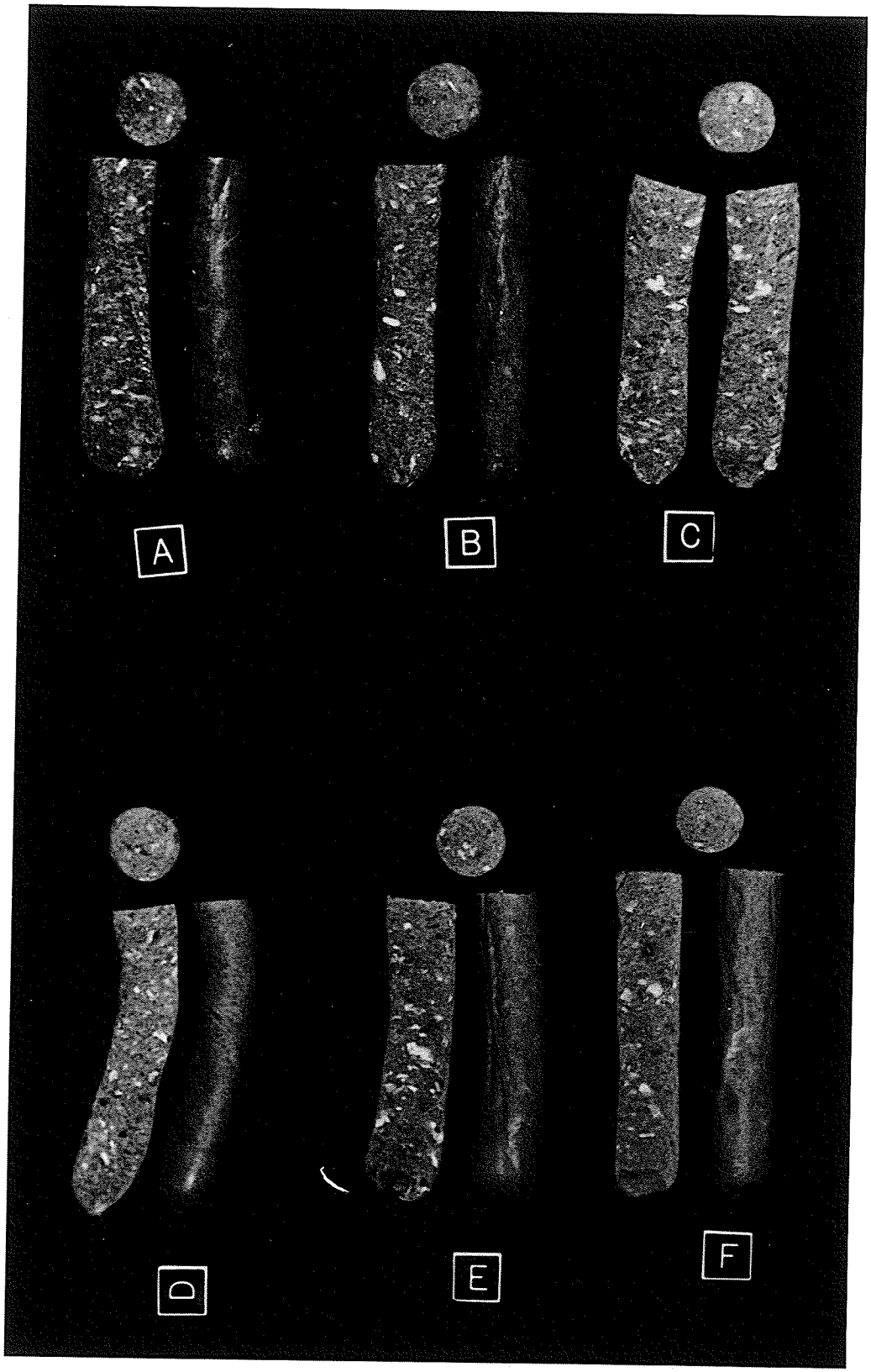


Table 21

TOTAL BACTERIAL COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT FAT SUBSTITUTED WITH VEGETABLE FAT AS AFFECTED BY VARIOUS PROCESSING TREATMENTS*

Level of Fat Substituted (%)	Colonies Per Gram			
	After Chopping	After Smoking	After Maturity	After Incubation (37°C, 48 hours)
0	205.8×10^3	115.0×10^1	134.0×10^1	152.0×10^1
10	212.4×10^3	132.0×10^1	144.0×10^1	149.0×10^1
20	193.2×10^3	133.0×10^1	145.0×10^1	155.0×10^1
30	215.4×10^3	132.0×10^1	139.0×10^1	158.0×10^1
40	215.0×10^3	131.0×10^1	144.0×10^1	155.0×10^1
50	199.6×10^3	134.0×10^1	155.0×10^1	160.0×10^1

*Mean of five trials, ref. Appendix XXXVIII.

Table 22

YEAST AND MOLD COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT FAT SUBSTITUTED WITH VEGETABLE FAT AS AFFECTED BY VARIOUS PROCESSING TREATMENTS*

Level of Fat Substituted (%)	Colonies Per Gram			
	After Chopping	After Smoking	After Maturity	After Incubation (37°C, 48 hours)
0	279.0	0.0	0.0	0.0
10	229.0	0.0	0.0	0.0
20	233.0	0.0	0.0	0.0
30	233.0	0.0	0.0	0.0
40	262.0	0.0	0.0	0.0
50	271.0	0.0	0.0	0.0

*Mean of five trials, ref. Appendix XXXIX

are shown in Table 23. Substitution at a level of 10 per cent of both the protein and fat exhibited no marked effect on the sausage emulsion. At the 20 per cent level of substitution, a slight decrease in the resilence of the emulsion was evident and became more remarkable with increasing levels of substitution. Consistency at 50 per cent level of substitution was soft and easy flowing. As have been previously observed, increasing lightness in emulsion color was readily observable with increase in the levels of protein and fat substituted.

Shear press values on the smoked sausages approximately paralleled those exhibited when only the fat was substituted, the values decreasing as the levels of protein and fat substituted increased (Table 24). This contrasted sharply with the shear press values for protein substituted sausages particularly at levels of replacement between zero and 30 per cent. Generally significant differences were determined for the six levels of treatment. The decreasing shear press values were linear in character as was readily observed in Figure 8. However, contrary to expectation, shear press values at all levels of replacements were below the corresponding values when meat protein and fat were individually substituted although only to a small degree.

Like in the previous series, color deterioration was observable, the magnitude varying with the level of

Table 23

COMPOSITION OF EMULSION, SMOKED AND MATURED SAUSAGES IN WHICH VARIOUS LEVELS OF MEAT PROTEINS AND FAT ARE SUBSTITUTED WITH VEGETABLE PROTEIN AND FAT*

Product	PER CENT PROTEIN AND FAT SUBSTITUTED																	
	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
Raw Emulsion	59.16	20.10	16.18	59.95	16.26	17.03	59.68	18.34	16.77	60.56	17.83	16.61	58.99	16.32	16.64	59.81	16.39	16.62
Smoked Sausage	58.31	16.01	16.77	58.61	16.38	16.37	58.94	16.76	16.69	58.29	16.15	17.21	58.85	16.05	17.02	58.75	16.10	16.30
Matured Sausage	24.77	31.70	31.15	22.38	28.49	32.34	24.99	29.27	30.69	26.19	30.53	30.44	24.37	29.73	31.72	28.05	30.58	30.35

*Mean for five trials, ref. Appendixes XIX, XX, and XXI

Legend M = Moisture

F = Fat

CP = Crude Protein

substitution as demonstrated in Figure 9 and Table 24. However the extent of variation was lower than when the protein and fat were individually substituted as the lower slope of the regression line indicated. A high correlation was determined for the treatment levels and the extent of color change. As indicated in Figure 15, smoked sausage color became progressively lighter as levels of 'Promine-D' and vegetable fat in the sausages were raised. A few large particles of connective tissue were also to be detected at the higher levels of substitution.

B. Matured Sausages

A clear pattern of dehydration of the matured sample did not emerge from the analysis featured in Table 23. While most of the different levels of substitution dehydrated below 25 per cent, both the 30 and 50 per cent levels of substitution analysed more than 25 per cent moisture.

Effect of the simultaneous substitution on shear press values was intermediate between those obtained when the protein and fat were substituted individually, although it was considerably lower than those from protein substituted sausages at almost all levels. More than 50 per cent reduction in shear press value was also induced by the simultaneous replacement of both protein and fat to the 50 per cent level.

Figure 15

THE EFFECT OF REPLACING MEAT PROTEIN AND FAT WITH VARIOUS LEVELS OF VEGETABLE PROTEIN AND FAT IN SMOKED SAUSAGES

A. 80 per cent meat protein and fat, 20 per cent vegetable protein and fat

B. 90 per cent meat protein and fat, 10 per cent vegetable protein and fat

C. 100 per cent meat protein and fat

D. 50 per cent meat protein and fat, 50 per cent vegetable protein and fat

E. 60 per cent meat protein and fat, 40 per cent vegetable protein and fat

F. 70 per cent meat protein and fat, 30 per cent vegetable protein and fat

Figure 15

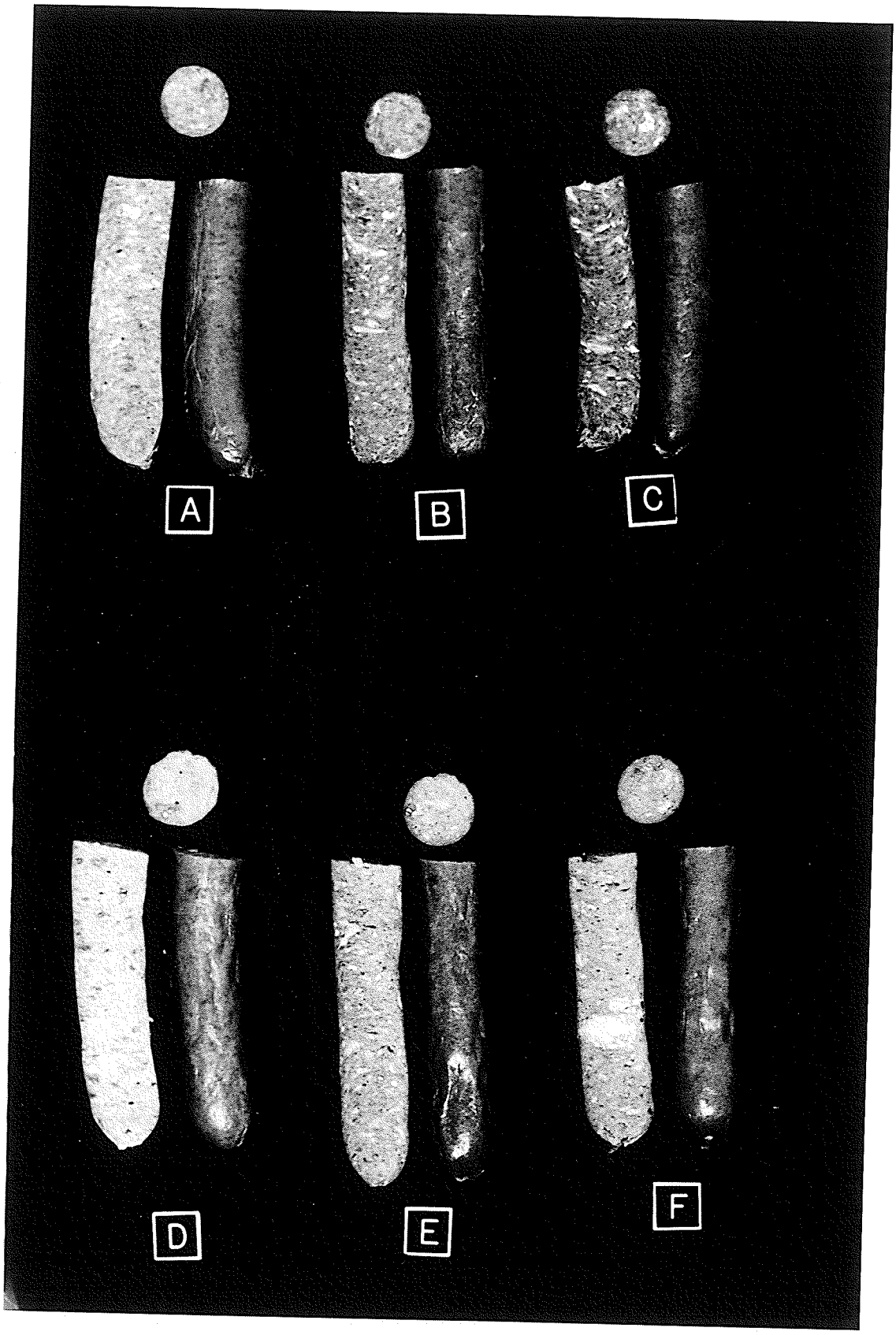


Table 24

TOTAL COLOR CHANGE AND SHEAR PRESS VALUES OF SMOKED AND MATURED SAUSAGES IN WHICH VARIOUS LEVELS OF MEAT PROTEINS ARE SUBSTITUTED WITH VEGETABLE PROTEIN*

Level of Substitution (%)	Color Change (Δ E)		Shear Press Values (lbs.)	
	Smoked	Matured	Smoked	Matured
0	-	-	262.0	370.0
10	1.18	3.11	315.0	414.4
20	2.13	1.8	235.0	608.0
30	2.37	3.95	183.6	609.4
40	2.84	4.85	147.0	535.0
50	5.41	5.28	139.0	443.4

*Mean of five trials

A similar trend in color change was also observed, the extent of color change being exactly intermediate to those of meat protein and fat substituted individually. However, extensive darkening resulting from the maturation was still readily observable.

C. Processing Effect on the Microflora

No significant differences could be observed in the extent of lethality of the combined action of smoke and temperature on the microflora of the smoked sausages at all the six levels of treatment. However, the bacteria load in all the six levels of treatment were reduced to well below 2,000 colonies per gram as a result of the smoking process (Table 25). Significant bacterialgrowth was also not observed during the ten days maturation period at 15^{o}C or the following incubation for 48 hours at 37^{o}C.

The effect on the yeast and mold cells featured in Table 26 showed a complete destruction or inhibition of these organisms as surviving cells were not observed after maturation or even after incubation at 37^{o}C.

5. SENSORY EVALUATION OF THE MATURED SAUSAGE SAMPLES

In order to gauge the acceptability of the different levels of substitution of meat protein and fat individually and collectively, sausage samples were submitted for evaluation to an eight-member panel on a nine point hedonic scoring scale. As could be seen in Table 27, both the first and second levels of treatment were consistently

Figure 16

THE EFFECT OF REPLACING MEAT PROTEIN AND FAT WITH VARIOUS LEVELS OF VEGETABLE PROTEIN AND FAT IN MATURED SAUSAGES

A. 100 per cent meat protein and fat

B. 90 per cent meat protein and fat, 10 per cent vegetable protein and fat

C. 80 per cent meat protein and fat, 20 per cent vegetable protein and fat

D. 70 per cent meat protein and fat, 30 per cent vegetable protein and fat

E. 60 per cent meat protein and fat, 40 per cent vegetable protein and fat

F. 50 per cent meat protein and fat, 50 per cent vegetable protein and fat

Figure 16

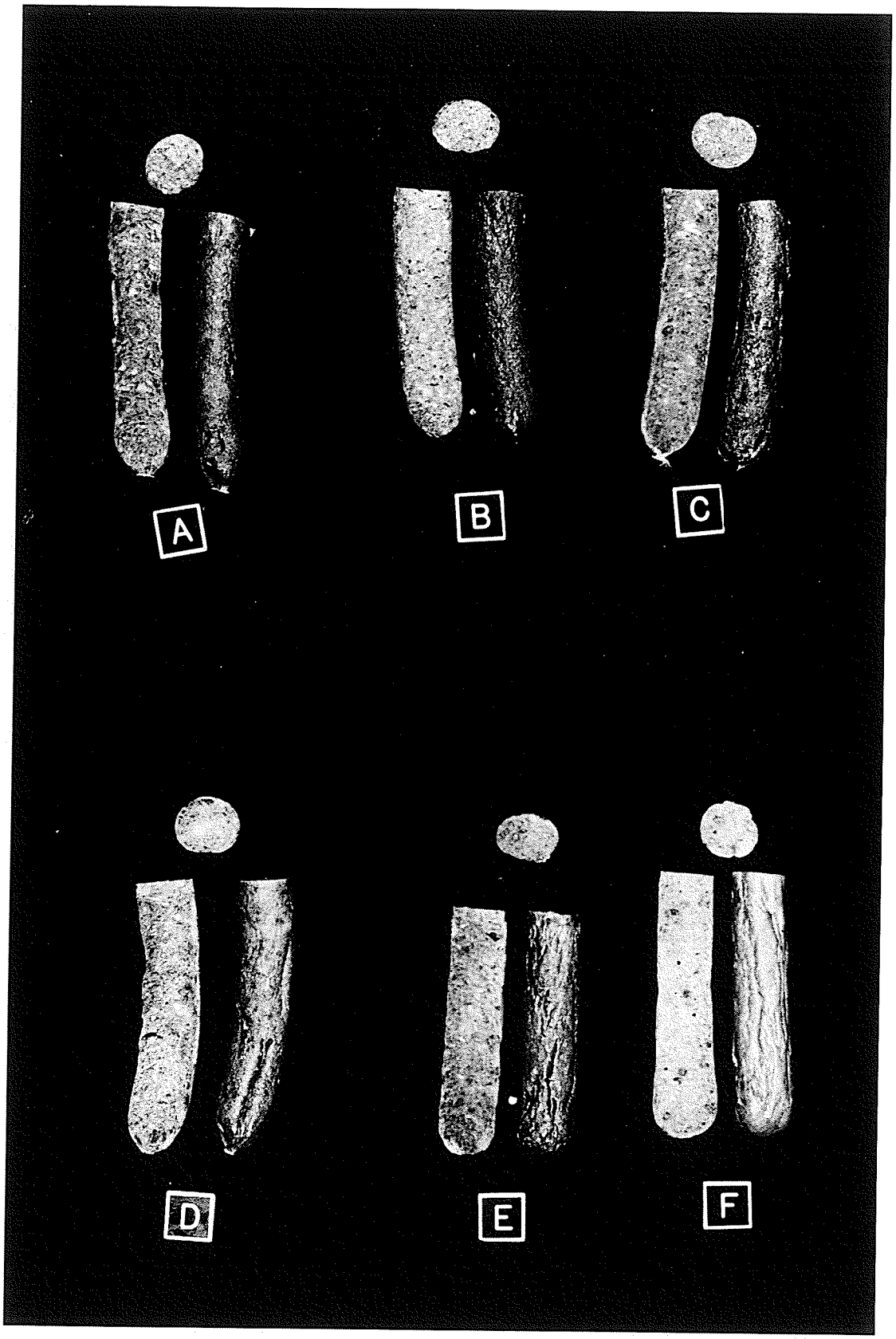


Table 25

TOTAL BACTERIAL COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEINS AND FAT SUBSTITUTED WITH VEGETABLE PROTEIN AND FAT AS AFFECTED BY VARIOUS PROCESSING TREATMENTS*

Level of Protein and Fat Substituted (%)	Colonies Per Gram			
	After Chopping	After Smoking	After Maturity	After Incubation (37°C, 48 hours)
0	217.6×10^3	124.0×10^1	141.0×10^1	154.0×10^1
10	233.2×10^3	126.0×10^1	138.0×10^1	156.0×10^1
20	221.2×10^3	124.0×10^1	140.0×10^1	153.0×10^1
30	215.6×10^3	119.0×10^1	135.0×10^1	151.0×10^1
40	237.6×10^3	127.0×10^1	150.0×10^1	166.0×10^1
50	210.0×10^3	118.0×10^1	146.0×10^1	152.0×10^1

*Mean of five trials, ref. Appendix XL

Table 26

YEAST AND MOLD COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEINS AND FAT SUBSTITUTED WITH VEGETABLE PROTEIN AND FAT AS AFFECTED BY VARIOUS PROCESSING TREATMENTS*

Level of Protein and Fat Substituted (%)	Colonies Per Gram			
	After Chopping	After Smoking	After Maturity	After Incubation (37°C, 48 hours)
0	270.0	0.0	0.0	0.0
10	259.0	0.0	0.0	0.0
20	270.0	0.0	0.0	0.0
30	240.0	0.0	0.0	0.0
40	275.8	0.0	0.0	0.0
50	254.2	0.0	0.0	0.0

*Mean of five trials, ref. Appendix XLI

rated higher than subsequent levels of treatment. In fact from the third level of treatment to the sixth level, flavor deterioration was evident as could be seen in the decreasing scale scores assigned to succeeding treatment levels. On the other hand, the average scale scores were approximately equal at zero and 10 per cent levels of substitution when meat protein was replaced with vegetable protein, meat fat was replaced with vegetable fat and when meat protein and fat were simultaneously replaced with vegetable protein and fat.

When meat protein was successively replaced with 'Promine-D', significant differences were determined between treatments but not between trials and panelists. Significant interactions were also observed between the panelists and the treatment but not between panelists and trials or treatment and trials. Progressive replacement of meat fat with vegetable fat elicited significant differences between the treatments and between the panelists but not between the trials. No significant interactions could be determined for panelists, treatments and trials. On the other hand, significant differences were observable between the treatments, panelists and trials when meat protein and fat were simultaneously replaced with vegetable protein and fat. Panelist-treatment interactions were also significant.

Table 27

HEDONIC RATING SCALE SCORES ON SAUSAGES IN WHICH VARIOUS LEVELS OF MEAT PROTEIN AND/OR FAT ARE SUBSTITUTED WITH VEGETABLE PROTEIN AND/OR FAT*

Meat Portion Substituted	Percent Meat Protein and/or Fat Substituted					
	0	10	20	30	40	50
Protein	5.5	6.7	4.8	5.3	4.8	4.8
Fat	6.4	6.3	5.3	4.5	4.6	3.3
Protein and Fat	6.6	6.6	5.8	5.5	4.3	3.8

*Mean of scale scores for eight panelists in five trials

Comments from panel members varied. In general the first two levels of substitution in the three series of treatments were classified as hard, chewy, dry and of superior texture. In the series in which meat proteins were replaced with vegetable protein, all samples were classified as hard. However, at the 40 and 50 per cent levels of substitution, samples were classified as of poor, flat and non-meaty flavor, while at the 30 and 40 per cent levels, the samples were judged as being rubbery. In the fat substituted series samples with 20 per cent level of substitution and above were classified as oily, greasy and soft. Some degree of mouth coating was also observed. Sausages in which both the protein and fat were simultaneously substituted elicited mixed response. Although the first three levels of substitution were all classified as hard, chewy and of good texture, succeeding levels were regarded as being softer and tallowy.

It may be observed that relevant data were statistically analysed for variability as reported in Appendixes XII to XXVI. The results indicated statistically significant differences in the parameters evaluated among the six levels of treatment in each of the three series of determinations.

DISCUSSION

Within the last few years, interest in the possible utilization of high quality proteins and fats from plar sources as substitutes for meat protein and fat have deepened. The present improved technology has made it possible to produce these proteins and fats in such forms as will replace their meat counterparts or supplement them for specific functions.

As was outlined under the scope of investigation, an attempt was made to determine the effect of substituting various levels of meat protein and fat with equivalent levels of processed vegetable protein and fat on certain parameters in a semi dried sausage type product. Specifically, 'Promine-D' and 'Crisco' shortening were used to replace meat protein and fat respectively and their effect on the color, texture and organoleptic properties of the sausage were determined in the matured product. Results from these findings indicated that both meat protein and fat could be substituted albeit at low levels with vegetable protein and fat with perhaps certain improvements in the texture and organoleptic properties of this type of sausage.

As was first established early in this investigation, the chemical composition of commercial pepperoni type sausages exhibited quite a wide variability. It was also

felt that in order for the experimental sausages to be relatively stable at ambient temperatures a reasonable state of dryness must be achieved. This state was achieved through two main steps: the elimination of added ice flakes to the basic formulation and the subjection of the smoked sausages to a ten-day maturation or ripening period at 15°C. Traditionally, the addition of ice flakes to a sausage emulsion was used to lower the temperature below 15°C which appeared to be a critical temperature for sausage emulsion stability. However, by using a partially defrosted meat, temperature rise during the processing period was kept below this critical level.

Preliminary trials on the smoke house were used to establish a smoking schedule which combined the desirable attributes of both cold smoke and hot smoke. This was evident as shown by the increased lethality on the natural sausage microflora. In fact, the final schedule reduced the surviving bacteria load by almost half. Some degree of dehydration of the smoked sausages also appeared to occur

In the investigation carried out to determine the effects of substituting meat protein with vegetable protein, specifically 'Promine-D', significant responses were observed at the various levels of substitution on the raw emulsion, smoked sausages and on the matured sausages. At both 10 and 20 per cent levels of substitution the physical characteristics of the raw emulsion were not dissimilar to that

of the all meat emulsion except for an apparent increase in viscosity resulting from the swelling action as the soy protein was dispersed in the available moisture. At higher levels of 'Promine-D' substitution, decreasing resilence of the emulsion resulted from the reduced level of meat tissue and a loss of shearing effect on the blade of the bowl chopper. The meat particles were therefore less fine chopped as the large specs of connective tissue in the smoked sausage would suggest. A corresponding reduction in the rate and extent of release of salt soluble protein from myosin would therefore affect the full emulsifying power of this protein.

Studies by Swift et al in 1961 indicated that the capacity of meat proteins to stabilize emulsions of fat could be as high as 1.61 gm. of fat per mg. protein. This capacity appeared to be well above that normally required to emulsify fat in sausage products in which the level of fat incorporation are of the order of 2 to 3 grams of fat per gram of protein. The reduction in the soluble protein extracted from myosin as a result of the diminution in shearing effect which accompanied the increase in the level of 'Promine-D' in the sausage batter would therefore not drastically affect the process of emulsion formation. However, emulsion stability could be expected to be marginal. This possibility was indicated by a few cases of fat cap formation in the smoked sausage when meat protein was substituted to a level of 50 per cent by 'Promine-D'.

In a preliminary experiment in which 'Promine-D' completely replaced meat lean in the sausage emulsion, extensive fat separation was observed in sausages utilising beef fat and 'Crisco' shortening respectively as source of fat. A similar result also occurred when meat and 'Promine-D' each supplied 50 per cent of the protein. It would therefore appear that under the condition of this study, 'Promine-D' by itself possessed very low emulsifying capacity. This finding could be supported by the work of Pearson et al in 1965 who demonstrated that at the pH range of meat 'Promine-D' was a poor emulsifier and that it probably served no major function in emulsifying fat when it was added to sausage products.

Results on shear press values of smoked sausages (Table 16 and Figure 8) however suggested some role of 'Promine-D' in stabilising meat soluble-protein induced emulsion. Substitution of meat protein by 'Promine-D' at a level of 10 per cent slightly increased the shear press values. Thus, while at the pH of meat, the role of 'Promine-D' per se as an emulsifier is doubtful, it obviously exerted an enhancing effect on the firmness and resilence of the sausage emulsion formed by the meat proteins at this low level. It may be pertinent to point out that at 10 per cent level of substitution, the added 'Promine-D' only contributed about 1.5 per cent of the green weight of the sausage or about half the level permitted by the Inspection Division of the

USDA in cooked sausages. At the 20 per cent level of substitution, the shear press value was slightly below that for the all meat sausage indicating a loss of the "resilence effect".

As was pointed out earlier, the shear press values for all the six levels of substitution increased significantly when the sausages were matured for ten days. All levels recorded higher shear press values than that featured by the all meat sausage. As Figure 10 shows,the curve for the change in shear press values due to the increasing level of substituting meat protein with 'Promine-D' was near sigmoidal in character. The crest for this curve was reached at substitution levels between 20 and 30 per cent, after which a tailing effect ensued. The region of this crest also approximates the levels (30 and 40 per cent) judged by some panel members during sensory evaluation as being rubbery. It would appear that with increasing levels of 'Promine-D' substitution, extent of denaturation and racemization of the proteins during maturation was of an increasing magnitude resulting in either increased toughness and/or springiness.

The color change in the smoked sausage was to be expected. Basically, smoked sausage color is a function of the density of the smoke constituents deposited, coloring effect of the added spices and to a very large extent on the cured pink color developed through the formation of

nitroso-hemochrome. 'Glycine-max'[6] the protein complex associated with soy products is not known to form any color with such ingredients as normally used in sausage production. Increasing the level of 'Promine-D' in the sausage batter will therefore parallel the reduction in the concentration of the pink pigment, nitrosohemochrome. This diluting effect of 'Promine-D' would appear to account for the increasing color change towards lightness observed as the level of 'Promine-D' was increased and that of meat protein reduced.

This phenomenon would in part account for the color change in the semi-dried or matured sausage. However, the extent of color change was of a lower order although all the treatment levels exhibited marked darkening effect. Also as the decrease in color gradient featured in Figures 9 and 11 would suggest, more extensive color darkening occurred at the higher level of substitution of 'Promine-D' than at the lower levels. At the low temperature utilised in the dehydration of these sausages, caramelization as the causative agent for the observed darkening could be ruled out. Carbonyl amino reactions involving the reactions of aldehydes, ketones and reducing sugars on one side and of amines, amino acids, peptides and proteins on the other, generally result in extensive browning reactions. All these are present in varying degrees in the experimental sausage

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[6] 'Glycine-max', believed to be the chief constituent protein of soy bean is of indefinite structure.

through the deposition of aldehyde from the smoke, addition of dextrose with the pepperoni spices and through the natural constituents of meat. However, the extent to which these contribute to the darkening of the sausage was not certain particularly at the low ripening temperature of 15°C.

The extensive dehydration of the sausages during the ripening process directly increased the apparent density of the sausages. This increased bulk density could be expected to affect the sausage color.

It is interesting also to observe that the incorporation of 'Promine-D' in the sausage formulation imparted marked effect on the morphology of the six matured sausage samples. At is obvious from Figure 12 sample A containing an all meat protein appeared to exhibit uniform degree of contraction during ripening as indicated by the small narrow but irregular furrows on the sausage skin. As the level of 'Promine-D' increased through to Sample F, a deepening and widening of these furrows appeared to suggest an increase in the extent of case hardening occurring on the sausage skin. The accompanying protein denaturation occurred to a larger extent on the outer zone than in the inner zone so that the resulting strain and stress would probably account for the deepening furrows. Studies carried out by Mihalyi et al in 1967 on Hungarian dry sausages attributed the extensive surface denaturation to the more rapid drying of the outer

zone which greatly promoted protein denaturation.

Increasing levels of 'Promine-D' also appeared to enhance greater dehydration as shown by the lower levels of residual moisture in the matured sausage.

The results obtained on substituting vegetable fat for meat fat in the sausage composition indicated gross changes on the sausage characteristics. As was indicated earlier, the production of a successful batter emulsion involved the complete entrapment of the fat globules by a thin film of soluble protein. Heat gellation of this film at the high temperature of smoking generally served to completely seal the fat within the protein matrix. It could be assumed that this same process generally occurred when meat fat was replaced by vegetable fat in the sausage batter. A direct effect of increasing the level of vegetable fat in the sausage batter was a progressive reduction in the sausage viscosity and consistency. Meat fat as normally used in sausage manufacture is structural in nature and assumes its characteristic resilence from the connective tissue strands or fibres surrounding the fat globules. The extent to which these connective tissues contribute to the characteristic texture is not defintely known. However, although this contribution is of a low order, its effect is no less significant as our studies indicated. The absence of this connective tissue in the vegetable fat could be expected to

reduce the sausage emulsion to a softer consistency as the level of vegetable fat was increased. Furthermore, beef fat at any temperature could also be expected to be of a harder consistency than the vegetable fat. This feature was reflected in our observations. The difference between beef fat which is yellowish and 'Crisco' shortening which is almost white also appeared to effect an increasing paleness with increase in the level of substitution.

Extensive fat separation was observed in the smoked sausages at 30 per cent level of substitution and above. This suggested extensive break down of the emulsion at these levels but not below them during the emulsion formation or during the hot smoking process. An insight into the possible causes may be gained by considering some aspects of emulsion formation. It is believed that the shearing action of the chopper blade was instrumental in reducing meat fat to small globules which were then readily enmeshed in the soluble protein matrix. In the presence of a large number of fat globules, the soluble proteins became limiting as a result of the increased surface area of the lipid exposed.

It would appear that in our studies, the vegetable fat, lacking the resilence of meat fat was easily degraded to a large number of very fine globules which therefore rendered the soluble proteins limiting. Thus the protein matrix formed were of a very low tenacity and were easily disrupted during hot smoking. The temperature required for

protein gelation far exceeded that required to melt the vegetable shortening. It would appear that this melted fat readily escaped through the weak points in the protein matrix prior to protein gellation. Beef fat with a higher melting point would exhibit this trait to a smaller extent.

As indicated in Figure 8, reduction in shear press values diminished linearly as the level of fat substitution increased. Similar relationship also occurred in the ripened sausage. However increase in toughness due to maturation was more marked in the all meat sausage and decreased progressively as the level of the vegetable fat was increased. Basically, the increased toughness observed on maturation could be attributed to the denaturation which accompanied dehydration. As previously observed, emulsion breakdown occurred resulting in fat separation during smoking. The rapid denaturation during ripening appeared to further reduce the aggregativeness of the protein matrix thus reducing their resistance to the shear press. Other evidence to support this theory on the formation of weak links in the protein matrix appeared to come from the extensive fat weeping which occurred during the ripening process.

The extent of color change in the matured sausage almost exactly paralleled that observed in the smoked sausage. In general, the extent of color change was related

linearly to the level of fat substituted and was more extensive than those experienced in the 'Promine-D' substituted sausage or that induced when both protein and fat were replaced simultaneously. The lack of difference in extent of color change in both the smoked and matured sausages will also appear to support our earlier theory that the color darkening observed in the matured sausages was a function of the quality of the protein and their probable reaction with other reactants present in the sausage. Since the protein present in all the six treatments on fat substitution were qualitatively and quantitatively similar, the same order of reaction involved in the darkening process should occur irrespective of the fat content. This reasoning appeared to hold with respect to the color change in both the smoked and the matured sausage.

Except for the color change and fat sweating, there did not appear to be any other morphological differences between the six levels of fat substitution either in the smoked sausage or in the matured sausages. However, contrary to our findings on protein substitution, increasing the level of vegetable fat appeared to interfere, albeit to a slight extent, with the extent of dehydration. As is obvious from Table 19, increasing the level of fat progressively increased the level of residual moisture in the matured sausage. Whereas in the emulsion, this order was

reversed.

The simultaneous replacement of both meat fat and meat protein with vegetable fat and protein appeared to exert intermediate effects on the sausage emulsion as were observed for the protein and fat when individually substituted. Shear press values approximately paralleled those for the fat substituted samples although these values were slightly but consistently lower. It would appear that in the smoked sausage, effects due to the vegetable fat were more pronounced than those due to 'Promine-D'. In the matured sausage, it would appear that the 'Promine-D' exerted a greater effect than that due to the vegetable fat as indicated by the intermediate position of this curve in Figure 10.

A cumulative effect of the simultaneous substitution of both meat protein and fat was observed in the matured sausage as indicated by its intermediate curve relative to the individual substitution. However, this order was reversed in the smoked sausages in which the color change appeared to have been of a lower order than those observed when both meat protein and fat were substituted individually. The reason for this reversal is not immediately obvious.

The formation of fat cap in the smoked sausage or of fat sweating in the matured sausage could be observed but were limited to only a few samples at the last two levels of substitution. This would suggest an intermediate effect on

the emulsion stability.

As revealed in Figure 16, the morphological characteristics appeared to be more affected by the 'Promine-D' content than the vegetable shortening. Thus at the higher levels of substitution, the typical furrows which were observed when 'Promine-D' was substituted individually were featured although to a smaller degree. This would also suggest that more case hardening did occur at these levels than at the lower levels of substitution.

The increasing level of dehydration also appeared to account for the relatively static state of microbial growth as a result of the change in the water activity index within the sausage. The high degree of dehydration resulted in a further concentration of the salt content thus enhancing its preservative effect. Our results would therefore indicate a reasonable stability of these sausages over a reasonable length of time.

The relative stability of the experimental sausages were evaluated by following the course of survival of the bacteria as well as the yeast and mold vegetative cells through all stages of processing. Further, an accelerated procedure was used to evaluate the keeping quality of the experimental sausages. Results from this investigation did not indicate any significant different trend for any of the three series of substitution levels. In fact for all

series and for all levels, the same general pattern of survival for both bacterialorganisms and the yeast and mold cells were evident.

It may be pertinent to point out that microbial populations of sausage samples used in this study were less than those commonly reported for samples of commercial sausages as handling of the meats was minimal in this study. As demonstrated in Tables 17, 21 and 25, slightly more than a hundred-fold reduction in the total bacteria load was achieved by the smoking schedule utilised during our investigation. At almost all levels of treatment, the surviving colonies were reduced to well below 2,000. The ten day maturation period and the subsequent incubation at 37^{o}C again failed to induce growth up to this level. The very slight growth obtained as a result of these two steps indicated an appreciable bactericidal and/or bacteriostatic effect due to the curing agents and hot smoking.

As was demonstrated by Halleck et al in 1956, the natural microflora of fresh meat were mainly of the non-pigmented Achromobacter-Pseudomonas group. The curing process generally induced succession by the Lactobacilli group of organisms most of which were killed during the subsequent hot smoking except for the small number of spores that may be present particularly of the Bacilli and Clostridia groups. Sodium nitrate present in the curing

mix generally served as a ready source of oxygen and nitrite which respectively create an aerobic atmosphere within the sausage and effectively inhibit germination and subsequent growth of Clostridia spores.

The smoking schedule utilised in this investigation combined both cold and hot smoking processes. At 90°F at which temperature the cold smoking was carried out for two hours and which appeared to be uptimum for the growth of micro-organisms, it would appear that bacteria cells were possibly activated to the growth and multiplication stages while induced germination of spores may have occurred. Increased sensitization during the immediately following hot smoking period generally resulted in a high level of lethality on the germinated and vegetative cells and a gross reduction in their number.

Further, the deposition of smoke constituents on the surface of the sausage sample appeared to exert a residual effect as reflected by the low level of growth during the ripening period and the subsequent incubation at 37°C. A similar trend on the yeast and mold cells appeared to have occurred as was evident by their complete elimination during the smoking process and their failure to grow during the following maturation at 15°C and the ensuing incubation at 37°C. Over extended storage period, further lethality

effect due to the smoke may be expected to occur as the smoke constituents penetrate towards the centre of the small diameter sausage.

Sensory evaluation of the sausage samples were carried out not only to evaluate their physical characteristics but also to estimate their relative acceptability. The hot flavor of the sausages and the relatively large number of samples determined during each sitting made the hedonic scaling method of evaluation ideal for our purpose. Furthermore, this method of evaluation appeared readily applicable to untrained panel members such as were utilised in these experiments.

Results of our investigation indicated that in 'Promine-D' substituted sausages scale scores were high in favour of samples in which meat proteins were substituted at 10 per cent level than the all meat sausage samples. These two were rated higher than samples from all other levels of substitution. In the fat substituted samples, both the first and second levels of substitution were rated superior to the others, the hedonic scores decreasing with increasing levels of substitution. Similar trend appeared to have occurred in sausages in which meat protein and fat were simultaneously replaced with 'Promine-D' and vegetable fat.

It would therefore appear that replacing meat protein with 'Promine-D' at a level of 10 per cent appreciably

improved its organoleptic properties while increasing this level had deteriorating effect on its qualities. No net improvement or deterioration in quality were obtained by substituting the fat at a level of 10 per cent either singly or simultaneously with 'Promine-D'. However, at higher levels, the decreasing ratings indicated gross deterioration in organoleptic properties. This deterioration paralleled increasing reports of greasiness as levels of substituted fat increased.

In order to meet the urgently needed level of high quality proteins in the diet of people in the developing countries, products such as were prepared in this work offer great promise. While soy bean is a very rich source of both protein and oil, such other sources as peanut and cotton are potentially significant in the production of processed vegetable proteins and fat for possible utilization in such meat products. The problem of refrigeration is greatly minimized by the semi-dried nature of the prepared sausages. Rapid improvements in the methods of protection and distribution will also ensure that such concentrated products reach the ultimate consumer in a wholesome state. However, as possible psychological bias may be a source of limitation as to their acceptance, consumer education may be necessary.

SUMMARY

In this study, meat protein and fat were replaced individually and simultaneously with 'Promine-D' and 'Crisco' shortening both of which were derived completely from vegetable sources. Results from this investigation indicated:

1. Substitution of meat protein with vegetable protein at a 10 per cent level improved appreciably both the physical and organoleptic properties of the semi-dry sausages.
2. Substitution of meat fat with vegetable fat at a 10 per cent level neither improved nor deteriorated organoleptic properties of the semi-dry sausages although slight deterioration in physical characteristics did occur.
3. Simultaneous substitution of both the meat protein and meat fat neither improved nor deteriorated the organoleptic properties of the semi-dry sausages although slight deterioration in physical characteristics did occur.
4. Substitution of both meat protein and fat individually or collectively with vegetable protein and fat at levels above 10 per cent induced gross deterioration in both

the physical and organoleptic properties of the semi-dry sausages.

5. Semi-dry sausages produced as outlined are stable over a reasonable period of a few days at ambient temperatures (70° to 90°F).

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APPENDIX I

COMPOSITION OF SOME COMMERCIAL PEPPERONI TYPE SAUSAGES

BRAND A

Sample No.	Moisture %	Fat %	Crude Protein %
1	39.10	32.36	17.85
2	40.50	30.90	17.74
3	41.10	30.36	17.80
4	40.70	30.40	17.30
5	39.50	31.60	17.10
Ave	40.18	31.12	17.55

BRAND B

Sample No.	Moisture %	Fat %	Crude Protein %
1	43.60	27.29	20.72
2	39.60	27.53	19.86
3	39.82	35.82	17.77
4	41.30	31.30	19.30
5	40.80	29.70	20.70
Ave	41.02	30.32	19.67

APPENDIX I (Cont'd)

COMPOSITION OF SOME COMMERCIAL PEPPERONI TYPE SAUSAGES (Cont'd)

BRAND C

Sample No.	Moisture %	Fat %	Crude Protein %
1	37.90	23.86	30.13
2	24.06	33.18	34.61
3	32.69	22.88	35.67
4	29.70	27.12	34.30
5	30.61	25.80	33.80
Ave	30.99	26.56	33.70

BRAND D

Sample No.	Moisture %	Fat %	Crude Protein %
1	22.03	35.98	31.39
2	20.08	37.63	27.27
3	21.96	33.03	28.19
4	24.70	34.70	29.30
5	23.10	35.50	28.89
Ave	22.37	35.37	29.01

APPENDIX II

CHAMBER TEMPERATURE (^{o}F) READINGS AT FIVE REPRESENTATIVE POSITIONS WHEN DESIRED TEMPERATURE WAS $90^{o}F$

Time in minutes	Position of Thermocouple*						
	1	2	3	4	5	Ave.	Range
0	120	140	130	120	78	117.60	52.0
10	102	105	104	103	90	100.80	15.0
20	95	95	95	95	95	95.0	0
30	95	95	95	95	95	95.0	0
40	90	92	90	92	90	90.8	2
50	90	90	90	90	90	90.0	0
60	90	90	90	90	90	90.0	0
70	90	90	90	90	90	90.0	0
80	90	90	90	90	90	90.0	0
90	90	90	90	90	90	90.0	0
100	89	89	88	88	89	88.6	1
110	89	88	89	87	85	87.6	4
120	88	88	88	88	88	88.0	0

*1. Right wall, about 5 inches below lower metal strip
2. Left wall, " " " " " " "
3. Centre of chamber
4. Back wall, about 5 inches below upper metal strip
5. Door Centre, " " " " " " "

APPENDIX III

CHAMBER TEMPERATURE (^{o}F) READINGS AT FIVE REPRESENTATIVE POSITIONS WHEN DESIRED TEMPERATURE WAS 100^{o}F

Time in minutes	Position of Thermocouple *						
	1	2	3	4	5	Ave.	Range
0	128	150	152	135	103	133.6	47.0
10	123	128	130	125	110	123.2	20.0
20	112	110	110	112	103	109.4	9.0
30	115	106	106	110	103	108.0	12.0
40	106	103	103	102	101	103.0	5.0
50	103	102	102	104	100	102.2	4.0
60	100	100	100	100	100	100.0	0.0
70	101	102	102	101	100	101.2	1.0
80	100	100	100	100	100	100.0	0.0
90	100	100	100	100	100	100.0	0.0
100	99	99	99	99	98	98.8	1.0
110	100	96	95	95	94	96.0	6.0
120	96	96	95	95	94	95.2	2.0

*As in Appendix I.

APPENDIX IV

CHAMBER TEMPERATURE (^{o}F) READINGS AT FIVE REPRESENTATIVE POSITIONS WHEN DESIRED TEMPERATURE WAS 120^{o}F

Time in Minutes	Position of Thermocouple*						
	1	2	3	4	5	Ave.	Range
0	136	123	123	132	100	122.8	36.0
10	103	100	100	100	99	100.4	4.0
20	150	135	137	152	120	138.8	32.0
30	123	120	120	125	113	120.2	12.0
40	137	135	130	132	120	130.8	17.0
50	125	122	122	125	117	122.2	8.0
60	127	123	123	130	117	124.0	13.0
70	130	122	122	130	114	123.6	16.0
80	123	121	121	125	118	121.6	7.0
90	121	120	120	122	117	120.0	4.0
100	120	120	120	120	113	118.6	3.0
110	120	120	120	120	117	119.4	3.0
120	120	120	120	120	120	120.0	0.0

*As in Appendix I.

APPENDIX V

CHAMBER TEMPERATURE (^{o}F) READINGS AT FIVE REPRESENTATIVE POSITIONS WHEN DESIRED TEMPERATURE WAS 140^{o}F

Time in Minutes	Position of Thermocouple*						
	1	2	3	4	5	Ave.	Range
0	120	127	135	120	100	120.4	35
10	195	180	175	180	168	179.6	27
20	100	103	105	103	105	103.2	5
30	160	170	160	160	160	162.0	10
40	135	146	160	140	158	147.8	25
50	130	131	150	136	138	137.0	20
60	127	125	141	133	145	134.2	20
70	140	135	150	150	150	145.0	15
80	138	138	152	139	138	141.0	14
90	135	138	150	137	139	139.8	15
100	133	139	143	138	138	138.2	10
110	138	136	150	139	138	140.2	14
120	135	137	145	138	137	138.4	10

*As in Appendix I.

APPENDIX VI

CHAMBER TEMPERATURE (^{o}F) READINGS AT FIVE REPRESENTATIVE POSITIONS WHEN DESIRED TEMPERATURE WAS 160^{o}F

Time in Minutes	Position of Thermocouple *						
	1	2	3	4	5	Ave.	Range
0	105	100	102	95	105	101.4	10
10	108	105	112	108	108	108.2	7
20	155	127	150	139	142	142.6	28
30	112	122	150	147	157	137.6	45
40	200	147	153	140	160	160.0	60
50	200	135	160	145	160	160.0	65
60	160	160	180	160	170	166.0	20
70	150	155	154	155	157	154.2	7
80	155	157	158	155	155	156.0	3
90	150	155	165	160	160	158.0	15
100	157	155	163	160	155	158.0	8
110	170	165	175	165	185	172.0	20
120	145	151	154	156	162	153.6	17

*As in Appendix I.

APPENDIX VII

TEMPERATURE (^{o}F) OF SMOKE CHAMBER AND SAUSAGE SAMPLES WHEN CHAMBER TEMPERATURE WAS MAINTAINED AROUND 90^{o}F

Positions*	1		2		3		4		5		Mean	
Time in Minutes	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.
0	61	35	134	32	67	33	68	33	68	34	79.6	33.4
10	90	63	97	65	93	62	89	63	91	64	92.0	63.4
20	88	70	111	71	96	69	96	68	110	69	100.2	69.4
30	84	71	94	72	89	71	86	69	89	70	88.4	70.6
40	89	73	103	73	90	72	89	71	98	72	93.8	72.2
50	95	76	105	77	95	74	93	73	100	74	97.6	74.8
60	92	76	98	80	91	76	89	77	91	78	92.2	77.4
70	91	77	97	81	90	77	86	78	93	79	91.4	78.4
80	92	80	98	83	91	80	88	80	95	80	92.8	80.6
90	90	79	95	82	89	79	87	79	93	80	90.8	79.8
100	90	80	95	83	90	80	85	80	94	80	90.8	80.6
110	88	79	94	81	94	79	85	81	93	82	90.8	80.4
120	90	81	95	84	84	80	90	81	90	81	89.8	81.4
130	90	82	95	84	90	81	85	81	93	82	90.6	82.2
140	89	82	95	84	88	81	85	82	93	82	90.0	82.2
150	86	82	93	84	86	81	83	82	87	82	87.0	82.2
160	88	84	93	85	88	81	84	82	90	82	88.6	82.8
170	90	84	95	85	83	83	85	83	92	82	89.0	83.4
180	90	84	94	85	86	83	87	83	91	81	89.6	83.2

*As in Appendix II, interior sensors were placed at centre of sausages adjacent to the chamber sensors.

APPENDIX VIII

TEMPERATURE (^{o}F) OF SMOKE CHAMBER AND SAUSAGE SAMPLES WHEN CHAMBER TEMPERATURE WAS MAINTAINED AROUND 100^{o}F

Positions*	1		2		3		4		5		Mean	
Time in Minutes	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.
0	94	35	122	39	102	40	90	37	105	40	102.6	38.2
10	98	70	130	70	104	74	98	71	107	70	107.4	71.0
20	91	75	115	76	100	78	95	77	100	76	100.2	76.4
30	95	77	110	78	103	79	95	77	102	78	101.0	77.8
40	97	79	110	80	104	80	95	80	103	78	101.8	79.4
50	97	78	110	82	105	82	96	80	105	81	102.6	80.6
60	103	79	100	83	113	83	103	80	103	82	104.4	81.4
70	104	79	99	84	112	84	103	82	103	84	104.2	82.6
80	97	80	113	85	107	85	95	83	103	84	103.0	83.4
90	115	82	106	89	110	89	110	84	117	88	111.6	86.4
100	97	84	105	94	105	94	96	85	105	92	101.6	89.8
110	95	85	110	94	104	94	95	91	104	92	101.6	91.2
120	97	87	107	95	104	95	95	93	105	93	101.6	92.6
130	99	89	110	96	105	96	97	95	106	96	103.4	94.4
140	100	90	109	97	105	97	96	94	106	97	103.2	95.0
150	107	90	103	94	114	94	102	92	104	95	106.0	93.0
160	106	91	102	93	112	93	103	92	103	95	105.0	92.8
170	109	92	101	93	104	93	102	93	103	95	103.8	93.2
180	106	92	101	92	103	96	102	93	103	95	103.0	93.6

*As in Appendix VII.

APPENDIX IX

TEMPERATURE (^{o}F) OF SMOKE CHAMBER AND SAUSAGE SAMPLES WHEN CHAMBER TEMPERATURE WAS MAINTAINED AROUND 120^{o}F

Positions*	1		2		3		4		5		Mean	
Time in Minutes	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.
0	99	41	149	40	123	35	93	40	106	37	114.0	38.6
10	118	64	105	65	95	65	96	63	105	64	103.8	64.2
20	112	74	138	75	112	75	112	75	133	75	121.4	74.8
30	110	83	129	89	107	91	103	86	125	90	114.8	87.8
40	150	94	119	100	128	100	130	99	131	98	131.6	98.2
50	139	97	119	100	122	100	126	99	126	99	126.4	99.0
60	139	100	111	102	123	102	125	100	124	101	124.4	101.0
70	141	102	117	103	124	103	124	102	124	102	126.0	102.4
80	140	108	110	107	125	107	124	105	124	107	124.6	106.8
90	122	110	131	114	120	114	110	113	132	114	123.0	113.0
100	130	108	112	111	122	112	117	111	118	110	119.8	110.4
110	112	109	120	111	116	111	137	110	146	109	126.2	110.0
120	144	109	123	110	129	110	122	109	129	108	129.4	109.2
130	149	113	123	116	133	116	132	114	134	113	134.2	114.4
140	141	111	120	110	124	110	123	110	124	111	126.4	110.4
150	134	110	112	108	120	108	117	108	118	109	120.2	108.6
160	117	109	127	110	127	110	110	109	123	110	120.8	109.6
170	112	108	123	110	115	110	108	110	121	110	115.8	109.6
180	115	108	124	110	115	110	109	110	121	110	116.8	109.6

*As in Appendix VII.

APPENDIX X

TEMPERATURE (^{o}F) OF SMOKE CHAMBER AND SAUSAGE SAMPLES WHEN CHAMBER TEMPERATURE WAS MAINTAINED AROUND 140^{o}F

Positions*	1		2		3		4		5		Mean	
Time in Minutes	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.
0	70	37	112	35	90	35	80	35	80	34	86.4	35.2
10	100	70	150	65	123	65	110	70	120	68	120.6	67.6
20	107	81	150	79	128	79	115	79	130	80	126.0	79.6
30	102	82	115	82	110	82	105	82	110	82	108.4	82.0
40	125	92	124	90	144	90	133	91	143	90	133.8	90.6
50	134	94	132	97	138	95	138	95	135	96	135.4	95.4
60	135	101	128	106	140	104	137	103	135	106	135.0	104.0
70	136	107	128	113	14	110	135	111	135	109	134.8	110.0
80	134	112	162	112	143	112	150	112	155	112	148.8	112.0
90	148	120	166	115	157	115	160	114	160	116	158.2	116.0
100	145	128	158	130	140	125	129	126	152	129	144.8	127.6
110	140	126	128	129	140	128	128	128	134	129	134.0	128.0
120	135	126	138	125	145	125	120	125	130	126	133.6	125.4
130	125	125	143	122	138	122	127	123	135	122	133.6	122.8
140	125	125	147	123	143	123	129	124	138	123	136.4	123.6
150	130	125	147	125	139	125	132	126	138	124	137.2	125.0
160	135	126	158	128	140	127	136	127	144	128	142.6	127.2
170	135	127	150	126	140	127	136	127	147	126	141.6	126.6
180	135	127	150	127	140	128	142	127	142	126	141.8	127.0

*As in Appendix VII.

APPENDIX XI

TEMPERATURE (^{o}F) OF SMOKE CHAMBER AND SAUSAGE SAMPLES WHEN CHAMBER TEMPERATURE WAS MAINTAINED AROUND 160^{o}F

Positions*	1		2		3		4		5		Mean	
Time in Minutes	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.	Chamber Temp.	Sausage Temp.
0	136	38	193	34	154	59	148	37	188	40	163.8	41.6
10	144	77	181	80	148	106	139	80	149	90	152.2	86.6
20	148	96	186	101	155	131	140	120	164	121	158.6	113.8
30	158	104	167	110	156	132	139	119	160	121	156.0	117.2
40	156	115	162	122	158	126	148	121	162	121	157.2	121.0
50	183	126	191	135	155	140	154	132	191	129	174.8	156.6
60	176	137	182	144	161	144	148	136	177	137	168.8	139.6
70	169	140	173	145	155	143	148	138	169	138	162.8	140.8
80	153	136	153	136	143	137	134	138	150	139	146.6	137.2
90	157	136	160	140	147	142	142	136	157	136	152.6	138.0
100	154	139	158	139	146	141	135	135	155	137	149.6	138.2
110	164	138	156	138	150	140	147	139	163	138	156.0	138.6
120	164	137	164	140	152	141	174	140	181	141	167.0	139.8
130	161	138	153	138	169	139	148	140	167	142	159.6	139.4
140	162	141	167	140	171	141	163	141	172	141	167.0	140.8
150	155	142	167	140	169	141	165	142	170	142	165.2	141.4
160	159	142	167	141	170	143	166	142	170	141	166.4	141.8
170	145	140	159	139	165	141	163	141	165	140	159.4	140.2
180	145	140	159	140	163	139	163	141	162	140	158.4	140.0

*As in Appendix VII.

APPENDIX XII

THE EFFECT OF VARIOUS LEVELS OF ADDED FLAKED ICE ON THE COMPOSITION OF RAW, SMOKED AND MATURED SAUSAGES

Level of added flaked ice		Raw Emulsion (Per cent)			Smoked Sausage (Per cent)			Matured Sausage (Per cent)		
		Moisture	Fat	Crude Protein	Moisture	Fat	Crude Protein	Moisture	Fat	Crude Protein
90.72 gm.	1	68.22	11.54	14.93	57.81	16.28	19.76	26.00	26.04	29.21
	2	67.61	12.25	14.76	59.07	13.84	19.28	34.00	23.21	31.65
	3	67.89	12.22	14.96	59.93	16.66	18.11	29.38	24.32	24.32
	4	67.83	12.14	14.21	62.15	13.60	17.69	28.57	21.76	34.56
	5	65.72	13.23	15.44	58.88	15.07	18.74	26.54	25.16	33.31
Mean		67.45	12.28	14.86	59.57	15.09	18.72	28.90	24.10	30.61
68.04 gm.	1	67.56	12.34	15.54	61.61	13.15	19.07	28.04	24.53	33.10
	2	67.91	11.54	16.29	59.82	13.52	19.71	27.78	26.12	26.12
	3	68.69	10.67	16.39	55.88	13.97	22.49	26.97	25.94	34.46
	4	64.96	14.19	16.15	59.07	15.60	16.23	26.61	23.17	33.74
	5	68.03	12.80	14.83	57.21	17.20	20.88	24.86	22.52	35.25
Mean		67.43	12.31	15.84	58.72	15.29	19.68	26.85	24.46	32.53
45.36 gm.	1	64.81	13.97	16.55	58.93	15.55	18.62	25.67	27.65	27.65
	2	66.21	13.61	15.43	55.81	18.31	18.78	29.99	27.67	23.40
	3	65.97	12.94	16.64	58.16	13.22	20.07	28.43	28.82	28.82
	4	67.88	11.30	16.30	58.06	15.82	18.69	24.20	28.84	28.84
	5	64.93	14.97	15.24	52.96	16.47	21.44	24.98	29.48	31.38
Mean		65.96	13.36	16.03	56.78	15.87	19.52	26.65	27.48	26.83

APPENDIX XII (CONT'D.)

Level of added flaked ice		Raw Emulsion (Per cent)			Smoked Sausage (Per cent)			Matured Sausage (Per cent)		
		Moisture	Fat	Crude Protein	Moisture	Fat	Crude Protein	Moisture	Fat	Crude Protein
22.68 gm.	1	64.88	15.42	15.04	54.15	16.68	21.75	26.00	26.32	33.45
	2	64.43	14.45	15.63	58.08	16.27	18.82	29.99	25.73	31.07
	3	62.88	14.54	16.74	53.08	19.52	20.05	26.48	28.77	28.77
	4	64.29	14.92	15.81	54.00	16.72	22.16	25.99	22.97	33.80
	5	64.06	14.67	16.39	59.47	12.00	21.96	25.18	26.76	32.59
Mean		64.11	14.80	15.92	55.76	16.25	20.95	26.72	26.11	31.94
0.0 gm.	1	60.87	14.97	15.79	54.90	16.34	20.31	25.62	27.21	30.28
	2	61.46	15.63	16.25	55.39	17.09	19.45	24.28	26.49	29.76
	3	60.03	14.82	17.01	56.58	17.56	19.87	25.09	28.01	29.46
	4	61.67	15.45	14.87	56.87	16.68	20.59	26.21	25.28	33.87
	5	60.82	15.87	15.34	55.91	16.49	20.08	24.60	26.77	32.09
Mean		60.97	15.35	15.85	55.93	16.83	20.06	25.16	26.55	31.15

APPENDIX XIII

COMPOSITION OF EMULSION HAVING VARIOUS LEVELS OF MEAT PROTEIN SUBSTITUTED WITH VEGETABLE PROTEIN

Trials	PER CENT PROTEIN SUBSTITUTED																	
	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
1	62.59	17.19	17.52	58.77	23.10	15.16	61.78	17.07	17.58	62.92	17.58	16.56	62.01	18.10	16.22	62.07	18.66	15.71
2	60.83	19.64	17.07	60.39	21.26	15.59	62.11	18.73	16.27	61.82	17.62	17.07	59.82	19.83	16.74	59.96	17.92	17.37
3	59.70	19.50	18.31	59.39	21.73	15.87	59.94	18.97	17.49	61.86	18.64	16.35	61.03	17.44	17.08	63.04	15.62	16.99
4	63.06	16.74	17.61	61.88	17.72	17.20	62.22	13.50	18.30	61.91	16.78	17.80	61.13	16.31	17.80	60.08	17.05	17.13
5	62.01	16.61	18.10	63.89	15.13	17.60	60.99	16.36	17.60	61.92	18.06	17.30	62.97	16.12	17.41	61.98	15.58	17.71
Mean	61.64	17.94	17.72	60.86	19.78	16.28	61.41	16.93	17.45	62.09	17.74	17.02	61.39	17.56	17.05	61.43	16.97	16.98

Legend M = Moisture

F = Fat

CP = Crude Protein

APPENDIX XIV

COMPOSITION OF SMOKED SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEINS SUBSTITUTED WITH VEGETABLE PROTEIN

Trials	PERCENT PROTEIN SUBSTITUTED																	
	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
1	58.96	16.74	16.47	58.78	20.74	16.12	60.04	15.94	16.54	59.96	16.19	17.27	57.96	16.08	17.14	61.02	14.35	18.03
2	60.93	14.78	16.92	57.58	20.62	16.53	59.90	18.52	16.87	60.00	15.01	16.92	59.68	16.99	17.34	57.82	18.68	17.28
3	60.86	14.99	16.47	59.10	14.16	17.26	59.96	14.87	17.00	60.91	15.52	16.98	58.66	17.85	16.74	58.87	15.41	17.06
4	58.01	13.98	18.09	58.92	16.05	15.31	60.17	14.45	15.79	61.29	14.13	16.03	59.97	14.86	17.22	58.69	15.89	16.39
5	61.51	13.23	17.14	60.01	13.99	18.29	59.69	13.86	16.96	61.27	14.39	15.87	58.08	14.66	17.11	58.44	15.64	16.35
Mean	60.04	14.74	17.01	58.88	17.11	16.70	59.95	15.52	16.63	60.69	15.05	16.61	58.87	16.08	17.11	58.96	15.99	17.02

Legend M = Moisture

F = Fat

CP = Crude Protein

APPENDIX XV

COMPOSITION OF MATURED SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEIN SUBSTITUTED WITH 'PROMINE-D'

Trials	PERCENT PROTEIN SUBSTITUTED																	
	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
1	28.97	26.03	30.23	27.92	33.11	29.69	20.98	31.21	32.87	30.39	20.06	33.87	25.99	28.01	30.32	25.84	27.24	31.50
2	29.87	22.60	32.15	25.98	30.71	29.46	24.99	25.52	32.06	23.97	30.10	31.97	19.96	28.16	31.97	19.97	28.87	33 17
3	23.74	32.18	31.77	25.67	29.69	32.01	32.98	31.83	31.63	24.19	30.65	31.83	25.92	30.37	31.5	26.00	24.78	32.43
4	23.99	29.22	32.31	22.07	25.37	31.89	21.78	25.61	34.01	20.01	32.63	31.69	19.99	34.27	27.89	23.80	31.00	29.87
5	24.06	25.48	33.86	23.82	31.01	31.97	20.02	26.60	31.89	24.16	32.03	31.97	23.85	32.20	32.67	20.00	25.57	33.56
Mean	26.13	27.10	32.06	25.09	29.98	31.00	22.15	28.15	32.49	24.54	29.08	32.27	23.14	30.6	30.87	23.12	27.49	32.106

Legend M = Moisture

F = Fat

CP = Crude Protein

APPENDIX XVI

COMPOSITION OF EMULSION HAVING VARIOUS LEVELS OF MEAT FAT SUBSTITUTED WITH VEGETABLE SHORTENING

	PER CENT FAT SUBSTITUTED																	
Trials	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
1	62.02	14.16	16.73	60.95	18.91	16.48	60.90	18.83	16.32	57.90	21.31	16.03	60.01	19.52	17.23	58.01	18.74	16.36
2	63.93	14.84	17.63	60.93	17.23	17.30	60.11	19.81	16.79	58.12	21.05	16.73	59.86	19.96	16.41	59.74	19.37	16.31
3	62.08	15.88	17.46	59.91	19.42	17.24	59.76	19.95	16.93	59.07	21.20	16.41	60.00	20.11	15.87	58.18	18.62	16.82
4	62.21	16.04	16.88	59.82	14.96	16.68	59.88	17.21	16.31	60.91	16.35	17.26	57.74	20.15	16.94	59.61	20.53	15.97
5	60.98	16.93	16.71	62.03	14.45	16.51	60.04	15.26	18.26	59.00	21.30	15.49	59.96	18.39	17.06	56.14	18.26	16.02
Mean	62.24	15.57	17.08	60.72	16.99	16.84	60.13	18.21	16.92	58.99	20.24	16.38	59.51	19.62	16.70	58.34	19.5	16.30

Legend M = Moisture

F = Fat

CP = Crude Protein

APPENDIX XVII

COMPOSITION OF SMOKED SAUSAGES HAVING VARIOUS LEVELS OF MEAT FAT SUBSTITUTED WITH VEGETABLE FAT

	PERCENT FAT SUBSTITUTED																	
		0		10			20			30			40			50		
Trials	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
1	59.69	19.97	15.23	59.88	13.27	16.93	59.69	13.96	17.79	59.09	13.81	17.04	58.98	16.10	17.21	61.18	12.91	18.23
2	56.90	13.96	18.21	58.96	16.28	17.33	59.02	15.78	17.49	58.83	14.61	18.01	59.76	17.11	16.92	58.84	20.23	15.97
3	58.96	14.95	17.49	59.01	17.46	16.91	58.44	16.02	16.99	58.41	18.12	16.87	59.21	15.77	16.83	59.89	14.77	16.49
4	54.95	16.90	15.87	58.20	16.16	16.81	54.89	16.08	18.24	53.83	19.76	18.09	54.08	19.17	15.97	53.85	18.85	17.93
5	58.16	13.51	18.39	58.10	15.92	17.29	54.07	16.87	17.31	51.96	19.09	18.63	55.90	18.33	17.69	59.87	18.24	16.45
Mean	57.73	15.85	17.04	58.83	15.82	17.05	57.22	15.74	17.56	56.42	17.08	17.73	57.59	17.29	16.92	58.69	16.92	17.01

Legend M = Moisture

F = Fat

CP = Crude Protein

APPENDIX XVIII

COMPOSITION OF MATURED SAUSAGES HAVING VARIOUS LEVELS OF MEAT FAT SUBSTITUTED WITH VEGETABLE SHORTENING

Trials	PERCENT FAT SUBSTITUTED																	
	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
1	27.42	28.31	31.65	27.98	30.81	30.87	29.72	31.33	28.65	30.01	26.14	29.63	33.80	26.14	28.64	28.64	25.89	31.06
2	30.15	24.20	29.71	27.50	33.59	28.77	27.49	34.91	29.01	40.04	23.68	25.89	38.69	24.56	28.09	34.71	25.95	27.63
3	29.22	25.84	30.23	25.43	31.97	29.36	31.20	33.53	29.02	27.07	26.46	30.36	34.90	33.06	25.03	32.86	28.96	28.99
4	28.13	27.45	29.93	26.00	21.80	33.97	26.10	27.32	31.40	29.05	34.47	29.65	29.53	33.07	28.92	30.83	32.69	28.59
5	24.03	26.40	31.53	25.89	25.51	32.61	28.00	29.13	30.02	26.76	32.91	31.09	27.91	35.05	30.32	30.01	34.72	28.63
Mean	27.79	26.44	30.61	26.56	28.74	31.11	28.50	31.24	29.62	30.58	28.73	29.32	32.96	30.37	28.20	31.41	29.64	28.98

Legend M = Moisture

F = Fat

CP = Crude Protein

APPENDIX XIX

COMPOSITION OF EMULSION HAVING VARIOUS LEVELS OF MEAT PROTEIN AND FAT SUBSTITUTED WITH 'PROMINE-D' AND VEGETABLE SHORTENING

Trials	PER CENT PROTEIN AND FAT SUBSTITUTED																	
	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
1	59.03	22.02	16.92	60.00	16.28	17.01	60.96	16.53	16.86	60.10	19.15	16.81	55.95	23.46	16.73	59.89	17.04	17.09
2	58.83	21.28	16.24	61.88	14.43	16.49	59.82	16.30	17.34	60.06	19.77	15.99	59.97	12.83	16.03	59.99	16.34	16.96
3	58.92	25.81	15.01	59.92	9.12	18.79	59.77	16.48	16.80	58.92	21.11	16.91	58.09	16.23	16.83	59.02	16.06	16.27
4	59.02	16.91	16.47	56.03	23.52	16.93	57.89	21.54	17.01	62.74	14.71	16.32	60.07	14.63	16.76	60.07	16.50	16.32
5	60.01	14.50	16.26	61.92	17.95	15.96	59.96	20.88	15.87	60.98	14.42	17.03	60.85	14.44	16.84	60.09	16.04	16.45
Mean	59.16	20.10	16.18	59.95	16.26	17.03	59.68	18.34	16.77	60.56	17.83	16.61	58.99	16.32	16.64	59.81	16.39	16.62

Legend M = Moisture

F = Fat

CP = Crude Protein

APPENDIX XX

COMPOSITION OF SMOKED SAUSAGES HAVING VARIOUS LEVELS OF MEAT FAT AND PROTEINS SUBSTITUTED WITH VEGETABLE SHORTENING AND 'PROMINE-D'

Trials	PER CENT PROTEIN AND FAT SUBSTITUTED																	
	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
1	59.67	15.08	15.23	58.73	15.50	16.54	60.01	14.87	16.74	55.76	17.49	16.93	60.29	15.57	16.93	59.41	16.63	16.38
2	56.89	18.42	16.36	59.24	16.62	15.69	57.23	17.45	17.23	59.28	17.15	17.81	57.12	17.39	15.87	58.37	16.09	15.72
3	58.47	16.92	17.21	57.94	15.97	17.09	58.64	16.06	17.48	58.64	16.22	17.29	58.09	16.82	16.26	57.32	17.21	15.89
4	58.81	15.11	16.75	58.40	16.81	16.44	59.72	16.95	16.73	59.68	15.23	16.03	58.95	14.39	18.21	59.32	15.34	16.39
5	57.69	14.51	18.31	58.74	16.98	16.09	59.08	18.47	15.29	58.08	14.67	18.01	59.81	16.07	17.85	59.34	15.25	17.12
Mean	58.31	16.01	16.77	58.61	16.38	16.37	58.94	16.76	16.69	58.29	16.15	17.21	58.85	16.05	17.02	58.75	16.10	16.30

Legend M = Moisture

F = Fat

CP = Crude Protein

APPENDIX XXI

COMPOSITION OF MATURED SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEIN AND FAT SUBSTITUTED WITH VEGETABLE PROTEIN AND FAT

	PER CENT PROTEIN AND FAT SUBSTITUTED																	
Trials	0			10			20			30			40			50		
	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP	M	F	CP
1	18.02	30.73	33.75	19.95	29.95	31.68	22.97	28.19	32.78	23.98	33.65	31.35	24.00	32.29	29.02	27.14	33.16	29.41
2	24.09	31.99	28.71	21.97	29.48	32.70	24.01	30.82	33.15	23.06	21.56	33.87	23.82	33.84	29.98	26.96	32.83	29.34
3	28.01	33.66	29.73	21.98	28.14	32.34	25.95	29.06	30.69	25.91	34.30	29.81	23.99	33.00	31.94	29.97	29.33	28.73
4	25.79	31.31	32.31	22.01	27.80	33.34	26.09	29.26	31.23	27.85	32.95	27.49	26.04	29.00	32.81	29.97	28.53	31.41
5	27.95	30.79	31.25	26.00	27.10	31.63	25.95	29.06	30.69	30.17	30.17	29.70	23.99	20.51	34.83	26.22	29.04	32.78
Mean	24.77	31.70	31.15	22.38	28.494	32.34	24.99	29.27	30.69	26.19	30.53	30.44	24.37	29.73	31.72	28.05	30.58	30.35

Legend M = Moisture

F = Fat

CP = Crude Protein

APPENDIX XXII

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT PROTEIN WITH VEGETABLE PROTEIN ON SHEAR PRESS VALUES OF SMOKED SAUSAGES

	Percent Protein Substituted					
Trials	0	10	20	30	40	50
			(lbs.)			
1	240	335	205	168	150	140
2	235	280	215	195	160	155
3	305	315	245	170	140	135
4	280	325	275	195	155	135
5	250	320	235	190	130	130
Mean	262	315	235	183.6	147	139

APPENDIX XXIII

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT PROTEIN WITH VEGETABLE PROTEIN ON SHEAR PRESS VALUES (LBS.) OF MATURED SAUSAGES

Trials	Percent Protein Substituted					
	0	10	20	30	40	50
	(lbs.)					
1	360	300	632	615	442	468
2	310	402	398	514	508	495
3	280	285	490	548	475	354
4	445	535	700	620	620	505
5	340	550	820	750	630	395
Mean	370	414.4	608	609.4	535	443.4

APPENDIX XXIV

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT FAT WITH VEGETABLE SHORTENING ON SHEAR PRESS VALUES OF SMOKED SAUSAGES

	Percent Fat Substituted					
Trials	0	10	20	30	40	50
			(lbs.)			
1	245	217	180	160	125	95
2	265	215	215	195	165	130
3	235	230	180	165	140	125
4	265	230	195	160	105	85
5	230	240	205	170	135	110
Mean	248	226.4	195	176	134	109

APPENDIX XXV

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT FAT WITH SHORTENING ON SHEAR PRESS VALUES OF MATURED SAUSAGES

	Percent Fat Substituted					
Trials	0	10	20	30	40	50
				(lbs.)		
1	345	290	250	245	217	190
2	350	352	290	290	210	200
3	440	350	245	196	190	180
4	365	310	270	240	212	150
5	390	340	305	260	185	180
Mean	378	328.4	272.0	246.2	202.8	180

APPENDIX XXVI

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT PROTEIN AND FAT SIMULTANEOUSLY WITH VEGETABLE PROTEIN AND SHORTENING ON SHEAR PRESS VALUES OF SMOKED SAUSAGES

	Percent Protein and Fat Substituted					
Trials	0	10	20	30	40	50
	(lbs.)					
1	220	220	180	170	125	130
2	245	205	185	135	120	90
3	265	215	190	145	145	110
4	235	240	205	165	130	95
5	245	225	210	165	145	105
Mean	242.0	221.0	194.0	158.0	133.0	106.0

APPENDIX XXVII

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT PROTEIN AND FAT SIMULTANEOUSLY WITH VEGETABLE PROTEIN AND FAT ON SHEAR PRESS VALUES OF MATURED SAUSAGES

	Percent Protein and Fat Substituted					
Trials	0	10	20	30	40	50
			(lbs.)			
1	381	358	317	433	200	182
2	410	400	360	292	196	172
3	455	451	445	288	168	194
4	491	433	360	322	192	190
5	362	418	400	252	210	173
Mean	419.8	412.0	376.4	317.4	193.2	182.2

APPENDIX XXVIII

COLOR CHANGE EXPRESSED AS △E VALUES OF SMOKED SAUSAGES WITH VARIOUS LEVELS OF MEAT PROTEIN REPLACED WITH VEGETABLE PROTEIN

	PERCENT PROTEIN SUBSTITUTED				
TRIAL	10	20	30	40	50
1	0.60	2.17	2.14	2.40	5.62
2	1.28	2.30	2.57	3.42	4.34
3	1.79	2.19	3.04	2.62	5.47
4	1.04	1.56	1.94	2.10	6.15
5	1.21	2.44	2.16	3.68	5.51
Mean	1.18	2.13	2.37	2.84	5.41

APPENDIX XXIX

COLOR CHANGE EXPRESSED AS Δ E VALUES OF MATURED SAUSAGES WITH VARIOUS LEVELS OF MEAT PROTEIN REPLACED WITH VEGETABLE PROTEIN

	PERCENT PROTEIN SUBSTITUTED				
TRIAL	10	20	30	40	50
1	3.11	1.60	4.15	5.02	5.50
2	3.07	2.23	3.28	5.10	5.47
3	3.06	2.03	4.58	4.37	4.87
4	2.62	1.37	3.21	4.22	4.71
5	3.69	1.79	4.56	5.54	5.86
Mean	3.11	1.80	3.95	4.85	5.28

APPENDIX XXX

COLOR CHANGE EXPRESSED AS Δ E VALUES OF SMOKED SAUSAGES WITH VARIOUS LEVELS OF MEAT FAT REPLACED WITH VEGETABLE FAT

	PERCENT FAT SUBSTITUTED				
TRIAL	10	20	30	40	50
1	2.67	3.13	6.07	9.40	9.95
2	1.30	3.12	4.65	8.70	10.35
3	1.62	3.07	4.93	8.77	10.08
4	2.26	3.58	6.14	10.06	9.62
5	1.41	3.60	4.29	9.43	9.88
Mean	1.85	3.30	5.21	9.27	9.97

APPENDIX XXXI

COLOR CHANGE EXPRESSED AS Δ E VALUES OF MATURED SAUSAGES WITH VARIOUS LEVELS OF MEAT FAT REPLACED WITH VEGETABLE FAT

	PERCENT FAT SUBSTITUTED				
TRIAL	10	20	30	40	50
1	3.16	4.69	5.98	8.00	8.93
2	2.92	4.29	5.54	8.39	8.72
3	2.76	4.99	5.69	8.38	8.34
4	2.96	3.59	5.57	7.78	8.69
5	2.65	4.19	4.91	8.54	7.82
Mean	2.89	4.35	5.53	8.21	8.50

APPENDIX XXXII

COLOR CHANGE EXPRESSED AS ΔE VALUES OF SMOKED SAUSAGES WITH VARIOUS LEVELS OF MEAT PROTEIN AND FAT REPLACED BY VEGETABLE PROTEIN AND FAT

	PERCENT PROTEIN AND FAT SUBSTITUTED				
TRIAL	10	20	30	40	50
1	1.19	3.09	4.83	4.88	6.50
2	0.65	3.10	4.56	5.44	5.83
3	1.87	3.52	5.40	6.56	6.60
4	1.07	3.20	4.64	5.76	6.47
5	0.47	2.82	4.14	4.21	5.22
Mean	1.05	3.14	4.17	5.37	6.12

APPENDIX XXXIII

COLOR CHANGE EXPRESSED AS ΔE VALUES OF MATURED SAUSAGES WITH VARIOUS LEVELS OF MEAT PROTEIN AND FAT REPLACED WITH VEGETABLE PROTEIN AND FAT

	PERCENT PROTEIN AND FAT SUBSTITUTED				
TRIAL	10	20	30	40	50
1	2.10	1.24	0.86	1.49	3.28
2	2.08	1.10	1.77	2.40	3.34
3	2.22	0.81	1.49	2.13	4.09
4	2.15	1.14	0.85	0.78	2.86
5	1.84	1.42	2.44	2.56	3.89
Mean	2.07	1.14	1.48	1.87	3.49

APPENDIX XXXIV

TOTAL BACTERIAL COUNT OF RAW EMULSION AND SMOKED SAUSAGES AS AFFECTED BY SMOKING TEMPERATURES*

Smoking Temp. (^{O}F)	Colonies Per Gram							
	Trials							
	1		2		3		Mean	
	Raw	Smoked	Raw	Smoked	Raw	Smoked	Raw	Smoked
90	$59.5x10^4$	$21.9x10^5$	$50.5x10^4$	$12.1x10^5$	$92.5x10^4$	$28.6x10^5$	$67.5x10^4$	$20.8x10^5$
100	$13.1x10^5$	$17.6x10^6$	$74.5x10^4$	$60.0x10^5$	$67.0x10^4$	$73.0x10^5$	$90.8x10^4$	$69.7x10^5$
120	$95.5x10^4$	$16.8x10^4$	$59.0x10^4$	$36.0x10^4$	$72.0x10^4$	$33.5x10^4$	$58.8x10^4$	$28.8x10^4$
140	$12.3x10^5$	$18.8x10^3$	$12.6x10^5$	$18.9x10^3$	$67.5x10^4$	$14.4x10^3$	$10.5x10^5$	$17.4x10^3$
160	$85.5x10^4$	$44.0x10^2$	$78.5x10^4$	$32.0x10^2$	$89.5x10^4$	$42.0x10^2$	$84.5x10^4$	$39.0x10^2$

*Mean of duplicate platings

APPENDIX XXXV

THE EFFECT OF SMOKING TEMPERATURE ON THE YEAST AND MOLD COUNT OF RAW AND SMOKED MEAT SAUSAGES*

Smoking Temp. (^{o}F)	Colonies Per Gram							
	Trials							
	1		2		3		Mean	
	Raw	Smoked	Raw	Smoked	Raw	Smoked	Raw	Smoked
90	$25.5x10^{1}$	$25.0x10^{1}$	$21.5x10^{1}$	$17.5x10^{1}$	$19.5x10^{1}$	$24.0x10^{1}$	$22.2x10^{1}$	$22.2x10^{1}$
100	$13.5x10^{1}$	$1.0x10^{1}$	$11.5x10^{1}$	$7.0x10^{1}$	$12.5x10^{1}$	$5.0x10^{1}$	$12.5x10^{1}$	$4.3x10^{1}$
120	$15.0x10^{1}$	$3.5x10^{1}$	$13.5x10^{1}$	$3.0x10^{1}$	$11.5x10^{1}$	$6.0x10^{1}$	$13.3x10^{1}$	$4.2x10^{1}$
140	$6.0x10^{1}$	$0.0x10^{1}$	$8.5x10^{1}$	$0.0x10^{1}$	$10.0x10^{1}$	$0.0x10^{1}$	$8.2x10^{1}$	$0.0x10^{1}$
160	$15.5x10^{1}$	$0.0x10^{1}$	$22.5x10^{1}$	$0.0x10^{1}$	$23.5x10^{1}$	$0.0x10^{1}$	$20.2x10^{1}$	$0.0x10^{1}$

*Mean of duplicate platings

APPENDIX XXXVI

THE EFFECT OF VARIOUS PROCESSING TREATMENTS ON TOTAL BACTERIAL COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEIN REPLACED WITH VEGETABLE PROTEIN

Levels of protein substituted	Trial	Colonies per gram			
		After chopping	After smoking	After maturity	After incubation (37°C, 48 hours)
0%	1	235×10^3	900	1,100	1,350
	2	210×10^3	1,000	1,500	1,450
	3	259×10^3	1,500	1,100	1,300
	4	223×10^3	1,200	1,350	1,600
	5	217×10^3	1,350	1,300	1,500
Mean		228.8×10^3	1,190	1,270	1,440
10%	1	272×10^3	1,600	1,300	1,550
	2	200×10^3	900	1,100	1,400
	3	214×10^3	1,600	1,000	1,250
	4	219×10^3	1,200	1,400	1,700
	5	231×10^3	1,400	1,500	1,650
Mean		227.2×10^3	1,340	1,260	1,510
20%	1	206×10^3	800	1,100	1,350
	2	186×10^3	1,200	1,400	1,550
	3	238×10^3	700	1,200	1,400
	4	241×10^3	1,300	1,600	1,750
	5	229×10^3	900	1,100	1,400
Mean		220.0×10^3	980	1,280	1,490
30%	1	205×10^3	900	1,100	1,350
	2	172×10^3	2,000	1,150	1,400
	3	191×10^3	900	1,000	1,350
	4	205×10^3	1,900	1,800	1,700
	5	241×10^3	1,200	1,350	1,550
Mean		202.8×10^3	1,380	1,280	1,490
40%	1	192×10^3	700	1,300	1,650
	2	249×10^3	800	1,350	1,500
	3	160×10^3	1,200	1,100	1,300
	4	235×10^3	1,400	1,500	1,650
	5	227×10^3	1,550	1,450	1,600
Mean		212.6×10^3	1,130	1,340	1,540
50%	1	236×10^3	500	1,000	1,300
	2	285×10^3	1,400	1,100	1,400
	3	245×10^3	1,000	1,300	1,450
	4	216×10^3	1,200	1,450	1,400
	5	201×10^3	1,100	1,250	1,700
Mean		236.6×10^3	1,040	1,220	1,450

APPENDIX XXXVII

THE EFFECT OF VARIOUS PROCESSING TREATMENTS ON YEAST AND MOLD COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEIN REPLACED WITH VEGETABLE PROTEIN

Level of protein substituted	Trial	Colonies per gram			
		After chopping	After smoking	After maturity	After incubation (37°C, 48 hours)
0%	1	240	0	0	0
	2	280	0	0	0
	3	290	0	0	0
	4	235	0	0	0
	5	210	0	0	0
Mean		251	0	0	0
10%	1	255	0	0	0
	2	250	0	0	0
	3	235	0	0	0
	4	220	0	0	0
	5	215	0	0	0
Mean		235	0	0	0
20%	1	200	0	0	0
	2	225	0	0	0
	3	275	0	0	0
	4	290	0	0	0
	5	260	0	0	0
Mean		250	0	0	0
30%	1	205	0	0	0
	2	175	0	0	0
	3	185	0	0	0
	4	240	0	0	0
	5	275	0	0	0
Mean		216	0	0	0
40%	1	295	0	0	0
	2	245	0	0	0
	3	285	0	0	0
	4	250	0	0	0
	5	235	0	0	0
Mean		262	0	0	0
50%	1	370	0	0	0
	2	280	0	0	0
	3	235	0	0	0
	4	250	0	0	0
	5	260	0	0	0
Mean		279	0	0	0

APPENDIX XXXVIII

THE EFFECT OF VARIOUS PROCESSING TREATMENTS ON TOTAL BACTERIAL COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT FAT REPLACED WITH VEGETABLE FAT

Level of fat substituted	Trial	Colonies per gram			
		After chopping	After smoking	After maturity	After incubation (37°C, 48 hours)
0%	1	191×10^3	1,250	1,500	1,500
	2	195×10^3	1,400	1,350	1,550
	3	205×10^3	1,100	1,400	1,650
	4	223×10^3	900	1,250	1,400
	5	215×10^3	1,100	1,200	1,500
Mean		205.8×10^3	1,150	1,340	1,520
10%	1	194×10^3	1,300	1,450	1,350
	2	199×10^3	1,150	1,350	1,500
	3	206×10^3	1,400	1,300	1,450
	4	234×10^3	1,250	1,400	1,450
	5	229×10^3	1,500	1,700	1,700
Mean		212.4×10^3	1,320	1,440	1,490
20%	1	190×10^3	1,350	1,400	1,400
	2	178×10^3	900	1,150	1,300
	3	190×10^3	1,750	1,650	1,750
	4	196×10^3	1,200	1,300	1,500
	5	212×10^3	1,450	1,750	1,800
Mean		193.2×10^3	1,330	1,450	1,550
30%	1	198×10^3	1,150	1,350	1,450
	2	208×10^3	900	1,100	1,350
	3	254×10^3	1,200	1,300	1,350
	4	224×10^3	2,000	1,700	1,950
	5	193×10^3	1,350	1,500	1,800
Mean		215.4×10^3	1,320	1,390	1,580
40%	1	210×10^3	1,250	1,400	1,500
	2	207×10^3	1,100	1,350	1,550
	3	203×10^3	800	1,100	1,350
	4	234×10^3	1,350	1,200	1,400
	5	221×10^3	2,050	2,150	1,950
Mean		215×10^3	1,310	1,440	1,550
50%	1	172×10^3	1,900	2,100	2,100
	2	203×10^3	800	1,000	1,100
	3	200×10^3	1,500	1,700	1,850
	4	209×10^3	1,300	1,500	1,550
	5	214×10^3	1,200	1,450	1,400
Mean		199.6×10^3	1,340	1,550	1,600

APPENDIX XXXIX

THE EFFECT OF VARIOUS PROCESSING TREATMENTS ON YEAST AND MOLD COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT FAT REPLACED WITH VEGETABLE FAT

Level of fat substituted	Trial	Colonies per gram			
		After chopping	After smoking	After maturity	After incubation (37°C, 48 hours)
0%	1	415	0	0	0
	2	315	0	0	0
	3	280	0	0	0
	4	180	0	0	0
	5	205	0	0	0
Mean		279	0	0	0
10%	1	200	0	0	0
	2	230	0	0	0
	3	205	0	0	0
	4	310	0	0	0
	5	195	0	0	0
Mean		229	0	0	0
20%	1	240	0	0	0
	2	210	0	0	0
	3	190	0	0	0
	4	220	0	0	0
	5	305	0	0	0
Mean		233	0	0	0
30%	1	235	0	0	0
	2	220	0	0	0
	3	175	0	0	0
	4	340	0	0	0
	5	210	0	0	0
Mean		233	0	0	0
40%	1	350	0	0	0
	2	260	0	0	0
	3	295	0	0	0
	4	190	0	0	0
	5	215	0	0	0
Mean		262	0	0	0
50%	1	270	0	0	0
	2	340	0	0	0
	3	355	0	0	0
	4	185	0	0	0
	5	205	0	0	0
Mean		271	0	0	0

APPENDIX XL

THE EFFECT OF VARIOUS PROCESSING TREATMENTS ON TOTAL BACTERIAL COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEIN AND FAT REPLACED SIMULTANEOUSLY WITH VEGETABLE PROTEIN AND FAT

Level of protein and fat substituted	Trial	Colonies per gram			
		After chopping	After smoking	After maturity	After incubation (37°C, 48 hours)
0%	1	242×10^3	900	1,250	1,500
	2	223×10^3	1,350	1,450	1,550
	3	216×10^3	1,500	1,700	1,700
	4	209×10^3	1,100	1,350	1,450
	5	198×10^3	1,350	1,300	1,500
Mean		217.6×10^3	1,240	1,410	1,540
10%	1	239×10^3	1,100	1,250	1,400
	2	219×10^3	1,500	1,450	1,550
	3	241×10^3	1,200	1,350	1,600
	4	186×10^3	1,000	1,200	1,450
	5	206×10^3	1,500	1,650	1,800
Mean		233.2×10^3	1,260	1,380	1,560
20%	1	183×10^3	1,600	1,700	1,900
	2	245×10^3	1,350	1,500	1,650
	3	249×10^3	1,150	1,400	1,400
	4	219×10^3	1,200	1,250	1,350
	5	270×10^3	900	1,150	1,350
Mean		221.2×10^3	1,240	1,400	1,530
30%	1	174×10^3	1,450	1,550	1,700
	2	229×10^3	800	1,200	1,500
	3	248×10^3	1,300	1,350	1,400
	4	219×10^3	1,250	1,400	1,600
	5	208×10^3	1,150	1,250	1,350
Mean		215.6×10^3	1,190	1,350	1,510
40%	1	256×10^3	1,100	1,350	1,550
	2	210×10^3	1,650	1,850	2,050
	3	221×10^3	1,350	1,550	1,600
	4	296×10^3	1,200	1,400	1,550
	5	205×10^3	1,050	1,350	1,500
Mean		237.6×10^3	1,270	1,500	1,660
50%	1	210×10^3	900	1,250	1,450
	2	195×10^3	1,100	1,400	1,400
	3	201×10^3	1,350	1,550	1,700
	4	225×10^3	1,400	1,650	1,500
	5	219×10^3	1,150	1,450	1,550
Mean		210×10^3	1,180	1,460	1,520

APPENDIX XLI

THE EFFECT OF VARIOUS PROCESSING TREATMENTS ON YEAST AND MOLD COUNT OF SAUSAGES HAVING VARIOUS LEVELS OF MEAT PROTEIN AND FAT REPLACED SIMULTANEOUSLY WITH VEGETABLE PROTEIN AND FAT

Level of protein and fat substituted	Trial	Colonies per gram			
		After chopping	After smoking	After maturity	After incubation (37°C, 48 hours)
0%	1	360	0	0	0
	2	240	0	0	0
	3	245	0	0	0
	4	270	0	0	0
	5	235	0	0	0
Mean		270	0	0	0
10%	1	340	0	0	0
	2	290	0	0	0
	3	270	0	0	0
	4	185	0	0	0
	5	210	0	0	0
Mean		259	0	0	0
20%	1	305	0	0	0
	2	330	0	0	0
	3	265	0	0	0
	4	200	0	0	0
	5	250	0	0	0
Mean		270	0	0	0
30%	1	185	0	0	0
	2	210	0	0	0
	3	210	0	0	0
	4	315	0	0	0
	5	280	0	0	0
Mean		240	0	0	0
40%	1	310	0	0	0
	2	265	0	0	0
	3	350	0	0	0
	4	219	0	0	0
	5	235	0	0	0
Mean		275.8	0	0	0
50%	1	285	0	0	0
	2	235	0	0	0
	3	180	0	0	0
	4	326	0	0	0
	5	245	0	0	0
Mean		254.2	0	0	0

APPENDIX XLII

HEDONIC RATING SCALE SCORES ON SAUSAGES WITH MEAT PROTEIN REPLACED WITH VARIOUS LEVELS OF VEGETABLE PROTEIN

Panelist	PERCENT MEAT PROTEIN AND FAT SUBSTITUTED																													
	0					10					20					30					40					50				
	TRIALS					TRIALS					TRIALS					TRIALS					TRIALS					TRIALS				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	7	8	5	6	5	8	6	7	6	5	4	6	5	5	5	3	4	4	5	3	5	5	4	4	4	4	5	2	2	3
2	7	6	6	6	6	7	6	7	7	6	6	6	2	2	4	6	4	6	3	5	7	4	6	2	4	4	2	6	3	4
3	5	6	5	6	6	8	8	6	5	6	4	7	3	6	4	7	5	7	7	5	2	5	4	4	3	7	1	6	4	4
4	3	4	7	5	5	7	7	7	4	6	3	3	4	4	4	3	5	5	5	5	6	4	3	5	5	4	5	4	5	4
5	4	5	4	4	8	8	8	7	7	6	4	7	4	5	4	4	4	3	8	7	7	7	5	6	7	7	7	6	6	5
6	4	8	8	6	6	6	6	7	5	6	5	4	4	4	3	6	6	5	4	4	4	4	6	4	5	3	7	4	4	4
7	8	7	6	7	9	7	8	8	8	9	6	6	7	6	7	6	6	6	7	6	6	7	4	8	8	7	8	8	6	5
8	5	6	5	8	7	6	7	7	7	7	4	5	5	7	6	7	3	4	6	5	5	3	4	4	3	3	7	6	4	4
Mean	5.4	6.3	5.8	6.0	6.5	7.1	7.0	7.0	6.1	6.4	4.5	5.4	4.3	4.8	4.6	5.3	4.6	5.0	5.6	5.0	5.3	4.9	4.5	4.6	4.9	4.9	5.3	5.3	4.3	4.1

APPENDIX XLIII

HEDONIC RATING SCALE SCORES ON SAUSAGES WITH MEAT FAT REPLACED WITH VARIOUS LEVELS OF VEGETABLE FAT

Panelist	PERCENT MEAT FAT SUBSTITUTED																									
	0					10					20					30					40					50				
	TRIALS					TRIALS					TRIALS					TRIALS					TRIALS					TRIALS				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	6	7	7	6	8	7	6	5	7	6	4	7	6	5	4	5	4	5	6	3	4	4	3	5	4	4	2	4	3	2
2	7	8	6	7	5	8	7	6	5	8	5	5	4	6	7	4	4	5	5	6	4	5	4	5	4	4	7	5	3	4
3	7	6	5	8	7	7	5	7	7	6	6	4	5	5	6	4	3	4	4	5	5	5	4	4	4	5	3	3	2	4
4	7	5	6	6	7	5	6	7	6	6	5	6	7	3	5	5	3	5	6	4	6	5	4	6	4	3	4	1	4	2
5	6	7	5	7	7	6	8	6	6	5	7	6	4	5	6	4	5	4	4	3	4	4	6	4	5	2	3	5	1	3
6	6	7	8	5	6	6	8	7	5	8	4	7	4	6	5	3	6	5	3	4	5	4	5	4	3	2	4	3	3	1
7	8	5	6	4	7	7	5	6	7	6	5	6	4	5	5	3	2	3	5	3	2	5	3	5	5	2	3	4	1	2
8	6	5	6	7	7	8	6	4	5	7	6	5	5	6	5	6	5	7	6	7	6	6	7	5	5	6	5	5	4	5
Mean	6.6	6.3	6.1	6.3	6.8	6.8	6.4	6.0	6.0	6.5	5.3	5.8	4.9	5.1	5.4	4.3	4.5	5.3	4.9	4.4	4.5	4.8	4.5	5.3	4.3	3.4	3.9	3.8	2.6	3.0

APPENDIX XLIV

HEDONIC RATING SCALE SCORES ON SAUSAGES WITH MEAT PROTEIN AND FAT REPLACED SIMULTANEOUSLY WITH VARIOUS LEVELS OF VEGETABLE PROTEIN AND FAT

Panelist	PERCENT MEAT PROTEIN AND FAT SUBSTITUTED																											
	0					10					20					30					40					50				
	TRIALS					TRIALS					TRIALS					TRIALS					TRIALS					TRIALS				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1	6	8	7	6	6	6	5	6	6	6	4	4	4	4	6	7	4	5	5	6	4	4	5	5	5	5	6	6	4	3
2	7	8	7	6	5	7	8	7	5	7	7	7	8	3	4	6	7	7	6	5	6	4	4	5	4	4	5	5	4	5
3	7	6	8	6	7	7	8	7	7	6	6	5	5	7	5	6	4	6	5	5	4	5	5	5	4	4	3	5	3	4
4	6	6	6	5	5	6	6	6	5	6	4	4	5	5	6	4	5	5	6	5	4	5	5	5	4	4	4	4	3	2
5	7	8	7	8	7	6	7	8	6	7	8	8	7	7	6	6	6	7	6	5	4	4	4	4	4	4	2	2	2	3
6	6	6	7	5	8	7	7	6	8	6	6	6	7	4	4	5	4	5	5	4	2	1	2	3	2	3	1	1	3	1
7	8	8	8	4	6	7	9	7	6	6	8	9	8	4	4	6	7	6	6	5	5	6	4	4	6	2	6	4	3	1
8	6	6	6	8	7	6	5	7	8	7	7	7	5	7	7	7	7	5	5	5	5	5	6	4	5	8	7	7	6	6
Mean	6.6	7	7	6	6.4	6.5	7.3	6.9	6.8	6.4	6.3	6.3	6.1	5.1	5.3	5.9	5.5	5.8	5.5	5.0	4.3	4.3	4.4	4.4	4.3	4.3	4.5	4.3	4.0	3.1

APPENDIX XLV

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT PROTEIN WITH VEGETABLE PROTEIN ON SHEAR PRESS VALUES OF SMOKED SAUSAGES

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Values
Treatments	5	119,916.00	23,983.20	60.39**
Trials	4	2,016.87	504.22	1.27
Exp. Errors	20	7,942.33	397.11	
Total	29	129,875.20		

F Values** Highly Significant

(Data from Appendix XXII)

APPENDIX XLVI

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT PROTEIN WITH VEGETABLE PROTEIN ON SHEAR PRESS VALUES (LBS.) OF MATURED SAUSAGES

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Values
Treatments	5	292,459.87	58,491.97	9.62**
Trials	4	150,322.14	37,580.53	
Exp. Errors	20	119,691.46	5,984.57	
Total	29	562,473.47		

F Values** Highly Significant

(Data from Appendix XXIII)

APPENDIX XLVII

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT FAT WITH VEGETABLE FAT ON SHEAR PRESS VALUES OF SMOKED SAUSAGES

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Values
Treatments	5	71,290.80	14,258.16	70.98**
Trials	4	2,681.67	670.42	3.34*
Exp. Errors	20	4,017.53	200.88	
Total	29	77,990.00		

F Values** Highly Significant

* Significant

(Data from Appendix XXIV)

APPENDIX XLVIII

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT FAT WITH VEGETABLE FAT ON SHEAR PRESS VALUES OF MATURED SAUSAGES

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Values
Treatments	5	141,171.30	28,234.26	36.61**
Trials	4	3,094.87	773.72	1.003
Exp. Errors	20	15,424.83	771.24	
Total	29	159,690.70		

F Values** Highly Significant

(Data from Appendix XXV)

APPENDIX XLIX

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT PROTEIN AND FAT WITH VEGETABLE PROTEIN AND FAT ON SHEAR PRESS VALUES OF SMOKED SAUSAGES

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Values
Treatments	5	69,256.7	13,851.34	78.00**
Trials	4	1,288.37	322.09	1.81
Exp. Errors	20	3,551.63	177.58	
Total	29	74,096.70		

F Values** Highly Significant

(Data from Appendix XXVI)

APPENDIX L

THE EFFECT OF SUBSTITUTING VARIOUS LEVELS OF MEAT PROTEIN AND FAT WITH VEGETABLE PROTEIN AND FAT ON SHEAR PRESS VALUES OF MATURED SAUSAGES

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Squares	F Values
Treatments	5	291,449.37	58,289.87	35.69**
Trials	4	5,151.00	1,287.75	0.79
Exp. Errors	20	32,664.63	1,633.23	
Total	29	329,265.00		

F Values** Highly Significant

(Data from Appendix XXVII)

APPENDIX LI

COLOR CHANGE EXPRESSED AS $\triangle$ E VALUES OF SMOKED SAUSAGES WITH VARIOUS LEVELS OF MEAT PROTEIN REPLACED WITH VEGETABLE PROTEIN

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Values
Treatment	4	50.4895	12.622	44.134*
Trial	4	0.9671	0.242	0.846
Error	16	4.5781	0.286	
Total	24	56.0347		

* Highly significant

(Data from Appendix XXVIII)

APPENDIX LII

COLOR CHANGE EXPRESSED AS Δ E VALUES OF MATURED SAUSAGES WITH VARIOUS LEVELS OF MEAT PROTEIN REPLACED WITH VEGETABLE PROTEIN

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value
Treatment	4	38.9164	9.7291	13.7982*
Trial	4	2.8731	0.7183	1.0187
Error	16	11.2813	0.7051	
Total	24	53.0708		

* Highly significant

(Data from Appendix XXIX)

APPENDIX LIII

COLOR CHANGE EXPRESSED AS Δ E VALUES OF SMOKED SAUSAGES WITH VARIOUS LEVELS OF MEAT FAT REPLACED WITH VEGETABLE FAT

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value
Treatment	4	257.9781	64.4945	273.0504
Trial	4	2.2628	0.5657	2.395
Error	16	3.7784	0.2362	
Total	24	264.0193		

* Highly significant

(Data from Appendix XXX)

APPENDIX LIV

COLOR CHANGE EXPRESSED AS Δ E VALUES OF MATURED SAUSAGES WITH VARIOUS LEVELS OF MEAT FAT REPLACED WITH VEGETABLE FAT

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value
Treatment	4	118.6338	29.6585	228.8465*
Trial	4	0.9826	0.2457	1.8958
Error	16	2.0728	0.1296	
Total	24	121.6892		

* Highly significant

(Data from Appendix XXXI)

APPENDIX LV

COLOR CHANGE EXPRESSED AS Δ E VALUES OF SMOKED SAUSAGES WITH VARIOUS LEVELS OF MEAT PROTEIN AND FAT REPLACED SIMULTANEOUSLY WITH VEGETABLE PROTEIN AND FAT

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value
Treatment	4	81.4862	20.3716	270.8989*
Trial	4	5.2724	1.3181	17.5279
Error	16	1.2036	0.0752	
Total	24	87.9622		

* Highly significant

(Data from Appendix XXXII)

APPENDIX LVI

COLOR CHANGE EXPRESSED AS △ E VALUES OF MATURED SAUSAGES WITH VARIOUS LEVELS OF MEAT PROTEIN AND FAT REPLACED SIMULTANEOUSLY WITH VEGETABLE PROTEIN AND FAT

A N O V A

Source of Variation	Degrees of Freedom	Sums of Squares	Mean Square	F Value
Treatment	4	16.2607	4.0652	22.5344*
Trial	4	2.3227	0.5867	3.2522
Error	16	2.8863	0.1804	
Total	24	21.4697		

* Highly significant

(Data from Appendix XXXIII)

APPENDIX LVII

HEDONIC SCALE SCORES ON SAUSAGES WITH MEAT PROTEIN REPLACED WITH VARIOUS LEVELS OF VEGETABLE PROTEIN

A N O V A

Source of Variation	Degrees of Freedom	Sum of S Squares	Mean Squares	F Values
Treatment	5	133.571	26.714	7.734*[a]
Panelists	7	25.896	3.699	1.071[a]
Trials	4	3.834	0.959	0.2776[a]
Interactions:				
Panelists x Treatment	35	234.630	6.704	2.061*
Panelists x Trials	29	51.299	1.769	0.544
Treatments x Trials	20	32.116	1.606	0.494
Error	139	452.152	3.253	
Total	239	606.896		

[a]Calculated using combined error variance of 3.454 with 223 degrees of freedom

*Highly significant

(Data from Appendix XLII)

APPENDIX LVIII

HEDONIC SCALE SCORES ON SAUSAGES WITH MEAT FAT REPLACED WITH VARIOUS LEVELS OF VEGETABLE FAT

A N O V A

Source of Variation	Degrees of Freedom	Sum of S Squares	Mean Squares	F Values
Treatment	5	286.85	57.37	47.928[a]*
Panelists	7	31.933	4.562	3.811*
Trials	4	1.692	0.423	0.353
Interactions:				
Panelists x Treatment	35	48.22	1.378	1.18
Panelists x Trials	29	34.108	1.176	1.008
Treatment x Trials	20	22.358	1.118	0.958
Error	139	162.239	1.167	
Total	239	587.4		

[a] Calculated using combined error variance of 1.197 with 223 degrees of freedom

* Highly significant

(Data from Appendix XLIII)

APPENDIX LIX

HEDONIC SCALE SCORES ON SAUSAGES WITH MEAT PROTEIN AND FAT REPLACED SIMULTANEOUSLY WITH VARIOUS LEVELS OF VEGETABLE PROTEIN AND FAT

A N O V A

Source of Variation	Degrees of Freedom	Sum of S Squares	Mean Squares	F Values
Treatment	5	260.771	52.154	39.391[a*]
Panelists	7	64.196	9.171	6.927[a*]
Trials	4	19.025	4.756	3.59[a]
Interactions:				
Panelist x treatments	35	112.729	3.221	3.369*
Panelist x trials	29	38.575	1.330	1.391
Treatment x trials	20	11.125	0.556	0.582
Error	139	132.771	0.95593	
Total	239	639.296		

[a] calculated using combined error variance of 1.324 with 223 degrees of freedom

* highly significant

(Data from Appendix XLIV)