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To the Graduate Council:

I am submitting herewith a thesis written by Eric Hwa-Lien Lee entitled "The Acceptability of Various Protein Concentrate Extenders in Summer Sausage." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Technology and Science.

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431

THE ACCEPTABILITY OF VARIOUS PROTEIN CONCENTRATE EXTENDERS IN SUMMER SAUSAGE

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

---

by

Eric Hwa-Lien Lee

August 1973

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ABSTRACT

The idea of adding protein concentrate to sausage products to increase the nutrition and reduce cost has been one concept of considerable study and experimentation. Three kinds of protein concentrates, fish protein concentrate, meat by-product protein concentrate and textured vegetable protein, were added to summer sausages at 4 and 8 percent levels. This study was undertaken to compare these products for chemical composition, physical quality and organoleptic acceptability.

From this study, significant differences were found in all the attributes, except color dominant wavelength and flavor between treatments. A significant treatment by replicate interaction was found in the measurement of moisture percentage, mechanical shear, dominant wavelength, texture and flavor in sensory evaluation which indicates a certain amount of instability in the experimental procedure.

Protein concentrate supplemented sausages had a higher protein content and a lower fat content than the all-meat control sausages. The available lysine content was significantly decreased after adding textured vegetable protein over 4 percent. There was no difference in available lysine content between sausage supplemented with fish protein concentrate or meat protein concentrate and the all-meat control sausages. More shear force was required to shear the sausages which were supplemented with meat protein concentrate or fish protein concentrate than the controls or textured vegetable protein supplemented sausages. There was no difference in shear measurement between all-meat control sausages

and textured vegetable protein supplemented sausages. There was no significant difference in dominant wavelength measurement among treatments. The greater the amount of protein concentrate added to sausages, the darker the color. In determining panel acceptance, sausages which contained 8 percent levels of fish protein concentrate, meat protein concentrate and textured vegetable protein, were scored less desirable in texture and appearance than sausages with 4 percent level. Sausages containing 8 percent level of meat protein concentrate and fish protein concentrate had higher scores than the all-meat controls and were less desirable in appearance and texture. The only sausages that were scored more acceptable in texture than the all-meat control sausages were those containing the 4 percent levels of fish protein concentrate and textured vegetable protein.

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CHAPTER I

INTRODUCTION

Protein deficiency is now widely recognized as a major nutritional problem in most of the technically underdeveloped and developing countries. Population in these areas is increasing at an exponential rate. Can enough low cost, high-quality protein be produced to meet the future needs of these countries? Researchers are being called upon to answer this critical world problem. The development of suitable combinations of protein concentrates to supply the quality and quantity of protein required in the diet is an important approach to alleviating this situation in areas where food products of animal origin are costly or limited.

For the time being, fish protein concentrate, meat protein concentrate, and soy protein concentrate are three major kinds of protein products available to combat the critical problem of protein malnutrition which is especially present in developing countries.

Traditionally, sausage has been manufactured from several different meats and other non-meat additives such as non-fat dry milk and cereal products. However, today the inadequate meat supply throughout the world and the high cost of the meat which does exist makes it necessary to use more economical high protein meat substitutes in sausage manufacturing.

Sausages are ideally suited for the addition of protein concentrates. Traditionally some sausages are formulated from the "scraps" of the meat industry. The finely chopped texture of this type of sausage

aids in disgusing the objectional characteristics of any individual component.

Consumer protection groups have in the past attacked sausage as being low in nutritive value, especially protein. Protein concentrates could not only decrease the cost of sausage products but could also increase the total protein content.

The objectives of this study were to compare three forms of protein concentrates (fish, meat by-product, soy bean) from an organoleptic, physic and chemical standpoing when used as a partial replacement for meat in a summer sausage formula.

CHAPTER II

LITERATURE REVIEWS

Sausage production is one of the rapidly growing, major industries in the United States of America. The Consumer and Marketing Service (C and M S) reported that 2,916,263,000 pounds of sausage were processed during the year 1970 (34). Although the USA has the largest cattle population in the world, it is also the world's largest importer of beef and veal (16). In the meat industry the rising demand for meat has continued over the postwar period and shows no sign of coming to an end. The price of meat shows the highest index number over the other food in the world food industry (14). One of the tendencies of the sausage industry today is to decrease the cost of sausage products and still maintain or improve the nutrition and organoleptic characteristics.

Various protein concentrates or additives are currently being used to enhance nutrition and decrease the cost of sausages and other processed meats. Soy protein has been used most extensively and fish protein has been used only slightly. Meat protein concentrate is a new product, not approved by the United States Department of Agriculture.

Soy protein concentrate (SPC) is defined as the product from high-quality, sound, clean, dehulled soybeans produced by removing most of the oil and water-soluble nonprotein constituents and contains not less than 70 percent protein (N X 6.25) on a moisture-free basis. Textured vegetable protein (TVP) is made by the extrusion-type processing of soy

flour to give a high-protein material capable of carrying a variety of colors and flavors.

Martin (30) reported that the use of SPC by meat processors helps to increase product yields, reduces costs, and that there is less cooking shrinkage. TVP can be produced with a meat-like appearance and eating characteristics which simulate comminuted meat items. Kies and Fox (20) found that TVP equals or exceeds the protein requirements of adult men. Wasileweki et al. (35) used "Promine D"--a soy protein concentrate--in Poland as 2-6 percent addition in the manufacture of ordinary sausage. Pro-lean™ (5), a new TVP product from Miles Laboratory, Indiana, has been used to extend meat patties, and produce a juicy, meat patty with less shrinkage and cooking losses. According to their study, Pro-lean™ can be used to replace costly lean meat, it is an excellent meat complement and has a high nutritional value with a protein efficiency ratio (PER) value of 1.94. Previous researchers (4, 2) reported that when soy protein concentrate was used in a sausage item, the protein content was increased, fat content was substantially decreased, the product possessed excellent acceptability and more importantly the raw material cost was appreciatly reduced.

Fish protein concentrate (FPC) is a product with a high biological value partially due to the high lysine content. Most of the time the FPC used in the foodstuffs provides a high nutritional value, but has a varied acceptability when added at different levels. Yanez et al. (36) added FPC to bread at 3, 6, 9, 10 and 12 percent levels; the 6 percent supplement of FPC was the most widely accepted of these fives levels.

Russo (31) reported that FPC blends well in cereals, beverages, soups, noodles, bread and cookies. Only small amounts of FPC (5-10 percent) are needed to be nutritionally significant, yet the products do not acquire undesirable taste and texture attributes.

Meat by-product protein concentrate (MPC) is made from by-products of cattle, hogs and sheep. It emerges as tasteless, odorless, finely-ground dry powder with 70 percent protein and 1 percent fat. Levin (25), inventor of a process for high protein concentrate extracted from fish, reported that MPC can be produced from meat by-products that are now being wasted, can be added to vegetable foods to increase their protein content or it can be reconstituted into other forms of food products. Levin (26) estimated that selling price of 25 cents per pound for MPC (equivalent to 5 pounds of meat) which is equivalent to high-protein isolates from vegetable sources and approximately the same price that is planned for fish protein concentrates. Although MPC is not permitted to be used as human food in the United States (31), it has been used in some other countries already. Gallert et al. (15) in Denmark reported that adding approximately 10 percent blood plasma to cooked sausage can improve the fat emulsification. Cselko et al. (13) found that the highest acceptable level of blood plasma addition in meat products is 10 percent. Russo (31) reported that these new sources of protein from meat wastes can be used as sausage extenders or as additives to vegetable protein. It is evident that MPC will soon be used for human consumption as a valuable source of protein in the food processing industry.

CHAPTER III

MATERIALS AND METHODS

I. PREPARATION AND TREATMENT OF SAMPLES

Twenty kilograms of pork trim and fifty-three kilograms of lean beef were included in this study. This meat raw material was obtained from a local meat packing plant and delivered to the University of Tennessee, Food Technology Building and stored at 0°C for one day prior to manufacturing of sausages.

The sausage product was prepared according to the procedure outlined in Figure 1. The pork trim and lean beef were ground through a 1/2 and 1/8 inch plate, respectively, and then tested for fat content by a modified Babcock method (32). The fat content was 50 and 10 percent, respectively, for the pork trim and lean beef. These two meat sources were uniformly blended to yield a mixture containing 21 percent fat.

This meat blend was then subdivided into 16 packages and frozen to await further processing. Two replications of eight packages each were randomly allotted to eight treatment groups. Six different products (treatments) were made by adding either 4 or 8 percent of fish protein concentrates (FPC), meat protein concentrates (MPC), or textured vegetable protein (TV). Treatments seven and eight had no protein additive substituted and served as controls for the two replications. The summer sausage formula used in this study is shown in Table I.

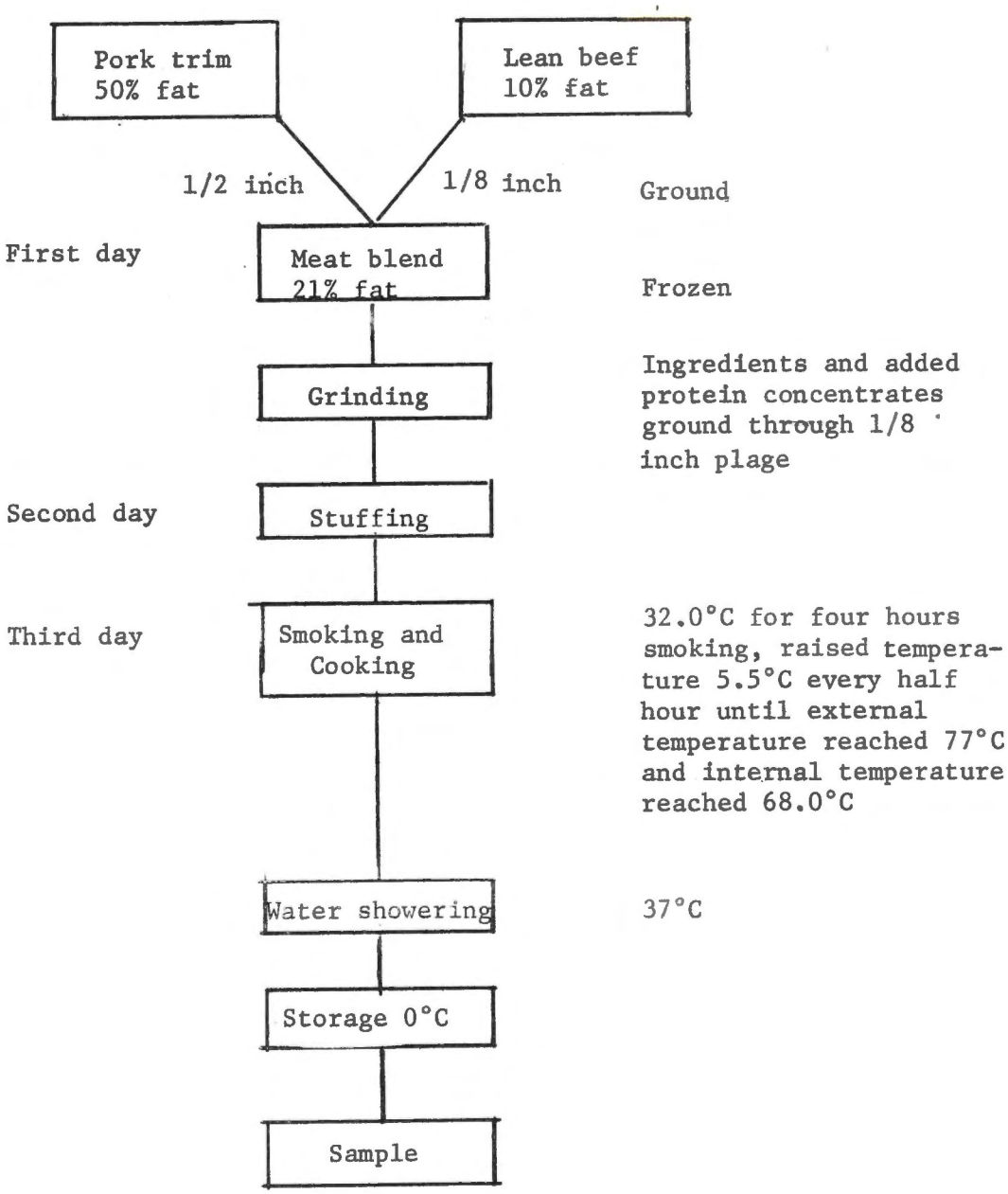

Figure 1. Diagram for the preparation of summer sausages. (Procedure used was obtained from Union Carbide Service Manual (3)).

TABLE I

SUMMER SAUSAGE RECIPE*

Treatment	Meat Mixture (21% fat)	Protein Concentrate
Meat Blend		
4 percent protein concentrate	4.35 kg.	0.18 kg.
8 percent protein concentrate	4.17 kg.	0.36 kg.
All-meat control sausage	4.53 kg.	0.0 kg.
Non-meat Additives		
Summer sausage seasoning		24 gm.
Salt		120 gm.
Sugar		24 gm.
Griffith Prague Powder--NaCl, NO_3+NO_2 (6.25%)		12 gm.
Griffith Sodium Erythorbate		2 gm.
Vinegar		30 ml.
Water added		1000 ml.

*The above formula with the exception of protein concentrates was proposed by B. Heller Spice Company, Chicago, Illinois.

The texture vegetable protein (TVP) used in this study is a product labeled Pro-Lean 45 which is produced by Miles Laboratories. It contains 63 percent protein and has a protein efficiency ratio (PER) of 1.94 compared to 2.5 for casein.

The fish protein concentrate (FPC) and meat protein concentrate (MPC) were obtained from VioBin Corp. The FPC contains 85 to 90 percent protein and is an odorless, tasteless powder, and has superior protein quality to casein (27). MPC is a defatted, deodorized powder which contains 85 to 90 percent protein and has a PER of 2.75 compared to 2.61 for casein. Amino acid percentages of both MPC and FPC are practically the same as lean muscle (28).

The meat mixtures were thawed after removal from the freezer. Curing and flavoring ingredients and the protein concentrates were added to the meat mixtures, blended, ground through a 1/8 inch plate and placed in a 0°C cooler. The following day the sausage was stuffed into Nojax brand (36 X 55), amber cellulose casings (Union Carbide Corp.) and again placed in the 0°C cooler. On the third day the sausage was smoked and cooked. The cycle began was a 32°C smoke for four hours after which the smokehouse temperature was raised 5.5°C every half hour until the external temperature reached 77°C and the internal sausage temperature reached 68°C. The sausages were showered with cold water (37°C) and stored in polyethylene bags at 0°C to prevent excessive moisture loss until analyses were performed.

II. METHODOLOGY

Chemical Measurement

Moisture, ether extract and nitrogen were determined by the Association of Official Agricultural Chemists methods (6). Sausage samples were sliced and finely ground before analysis.

Available Lysine Determination

The method described by Kakade and Liener (19) was used to determine available lysine content in 100 grams of protein.

Color Measurement

Color measurements were made on a Hunter Digital Color Difference Meter (Model D250 2M/L, Hunter Associates Laboratory, Fairfax, Virginia) to measure the tristimulus values of the samples. To make this measurement, a reference standard (Illuminant "C-barium Sulfate Standard number D25 C2-136) was used to calibrate the instrument before use. Samples which were ground very finely before measurement were placed over the sample port and three readings were taken for each sample. The values taken from the instrument were the Commission International de L'Eclairage (C.I.E). X, Y and Z values from which were used to calculate the chromaticity coordinates x and y. Purity and the dominant wavelength were obtained by reference to the C.I.E. chromaticity diagram (17).

$$x = X/(X+Y+Z)$$

$$y = Y/(X+Y+Z)$$

Texture Measurement

An Allo-Kramer shear press (Model SP-12) was used to determine

the texture of the sausage samples (21, 22, 23). A 250 pound proving ring was used with a 20 second thrust. The samples used for this measurement were sliced vertically against the link of sausage. Thickness of each sample slice was 6 mm., and the diameter was 29 mm. Four slices were placed in the standard shear-compression cell for testing. The values recorded were converted to equivalent pounds force by use of a standard curve. The force required to shear the sample is reported in kilograms force.

Sensory Evaluation

Test methods. Two organoleptic tests for each replicate were used to evaluate texture, flavor, appearance and overall acceptability of the samples. A difference test (1, 24) was conducted to evaluate texture, flavor, and appearance. A hedonic preference (24) test was used to evaluate the overall acceptability and to determine the degree of acceptance for each sample. A nine-point scale was used with the description ranging from "like extremely" to "dislike extremely." The descriptive terms on the score sheet were assigned a numerical value for analysis of the data with values ranging from one to nine. The sensory evaluations were replicated four times.

Sensory panel. Untrained panel members, composed of graduate students and staff members of the Food Technology and Science Department, participated in the sensory evaluations. In order to work with an equal number of observations, fifteen members' data were selected

randomly from 17-19 members' observations for the analysis. A general agreement on the meaning of the descriptive terms used in the scoring test was established prior to tasting of the sausages.

Test procedures. The two groups of samples, each consisting of 3 slices selected at random, were placed on paper plates which were divided into two groups and identified by three-digit numbers. The first group was used for the difference test of texture, flavor, and appearance. One of the control samples was used as a reference (R), to evaluate the other samples. The second group, having different codes from the first group, was evaluated for overall acceptability. No reference was used in this test.

III. STATISTICAL ANALYSIS

The Statistical Analysis System (8) computer program at the University of Tennessee Computer Center (UTCC) was used for the calculation of analysis of variance. Data on all measurements were analyzed as a Nested Factorial Design. Correlation coefficients between shear values and texture scores from taste panel were analyzed. Differences between means were analyzed by the Duncan's Multiple Range Test (33).

The statistical model, sources of variation and expected mean squares for each source of variation used for the analysis of variance in this research are shown in the Appendix A.

CHAPTER IV

RESULTS AND DISCUSSION

I. EFFECT OF PROTEIN CONCENTRATES ON THE CHEMICAL COMPOSITION OF SUMMER SAUSAGE

The summary of the analysis of variance for the effects of protein concentrates on the chemical composition of summer sausage is shown in Table II. There was a significant difference in fat, protein, and moisture content among treatments. A significant treatment - replicate (T x R) interaction was observed for percent moisture which indicates a possible lack of control on moisture content during the processing of the sausages. Since the smokehouse did not have humidity control, this variation might have been expected. Most modern sausage manufactureres today have controlled cooking and smoking units, however, some are processing with units much like the one used in this study. Treatment means for moisture, fat and protein are presented in Table III. Significant means were observed for moisture among treatments, however, due to the significant T x R interaction, meaningful conclusions cannot be made with confidence.

The fat and protein content of the sausages apparently was not affected by the lack of humidity controls on the cooking and smoking unit.

The control sausages had significantly higher levels of fat than all protein supplemented sausages. These results are in agreement with

TABLE II

ANALYSIS OF VARIANCE FOR THE EFFECT OF PROTEIN CONCENTRATES ON THE CHEMICAL COMPOSITION OF SUMMER SAUSAGE

		Mean Squares		
Source	D.F.	Moisture (Percent)	Fat (Percent)	Protein (Percent)
Replication	1	3.375*	14.563**	1.215
Error A[1]	4	0.406	0.626	1.505
Treatment	7	27.780*	15.302**	41.667*
T x R	7	5.446**	1.154	1.395
Error B[2]	28	1.395**	1.416**	0.645
Residual Error	48	0.313	0.437	0.321
Total	95	3.059	2.030	3.602

[1]Days within replication used to test replication.

[2]Treatment by day interaction within replication for testing treatment.

*Significant at the 0.01 level of probability.

**Significant at the 0.05 level of probability.

TABLE III

EFFECT OF PROTEIN CONCENTRATES ON THE CHEMICAL COMPOSITION OF SUMMER SAUSAGE

Treatment[1]	Means[2,3]		
	Moisture (Percent)	Fat (Percent)	Protein (Percent)
FPC (4 percent)	50.4^{abc}	21.9^{m}	20.7^{v}
FPC (8 percent)	48.4^{c}	21.6^{mn}	23.1^{s}
MPC (4 percent)	50.1^{bc}	22.1^{lm}	22.0^{t}
MPC (8 percent)	48.8^{c}	20.6^{no}	24.6^{r}
TVP (4 percent)	51.3^{ab}	21.2^{mno}	21.0^{vw}
TVP (8 percent)	51.8^{ab}	20.1^{o}	21.5^{tu}
Control 1	52.1^{ab}	23.0^{kl}	19.4^{w}
Control 2	52.6^{a}	23.4^{k}	18.9^{w}
$S_{\bar{X}}$	0.674	0.344	0.232

[1]FPC - fish protein concentrate
MPC - meat by-product concentrate
TVP - textured vegetable protein

[2]Means of 12 observations.

[3]Means within the column followed by the same letters are not significantly different at the 0.05 level of probability.

previous reports (4, 10) which observed that an increase in soy protein supplement caused a decrease in fat and an increase in protein percentage of sausage products. In this study an increase in protein supplement from 4 to 8 percent did not significantly decrease fat percentage in FPC and TVP contained sausages, however, a significant decrease was observed in the MPC sausages. When the protein level of any product is increased, a subsequent decrease in fat content is expected. This was observed in the MPC supplemented sausages but not for the other two types.

It is also known that certain proteins have superior fat binding capacities. In this study the MPC was largely denatured in its manufacture and had low water solubility when added to the sausage product. The TVP and FPC apparently had a greater ability to bind fat thus when higher levels were added to the sausages less fat escaped during cooking. This then could explain why no difference in fat percentage was observed between sausages supplemented with 4 and 8 percent FPC and TVP.

Control sausages were observed to contain less protein than those supplemented with the protein additives. With the exception of TVP contained sausages, those supplemented with 8 percent levels were significantly higher in protein than those supplemented with 4 percent levels. At the 8 percent level, sausages supplemented with MPC was significantly higher in protent content than those supplemented with FPC.

II. EFFECT OF PROTEIN CONCENTRATES ON THE AVAILABLE LYSINE CONTENT OF SUMMER SAUSAGE

The summary of the analysis of variance for the effect of protein

concentrates on the available lysine content of summer sausages is shown in Table IV. A significant affect among treatments was observed. Treatment means for the different sausages are shown in Table V. These data indicate that the addition of 4 and 8 percent of FPC to summer sausages did not significantly increase the available lysine content when compared to all-meat controls or to those sausages supplemented with 4 and 8 percent of MPC. However, a significantly higher available lysine content was observed in FPC added sausages than in TVP added sausages. Thus, it appears that in this study, fish protein contains higher available lysine than soybean and meat protein although a significant difference was not found between FPC and MPC supplemented sausages. The difference between the 4 and 8 percent levels was insignificant in each case. Carpenter and Ellinger (11, 12) reported higher available lysine in various fish products than in either meat or casein samples. In their study, the inference was drawn that available lysine tests were good indicators of gross protein value. Presently, the trend in the meat processing industry is for an increased usage of textured vegetable proteins. If available lysine tests are in fact good indicators of protein quality and if addition of higher levels of TVP lowers lysine content of sausages, then availability could be an important consideration when determining acceptable upper limits for TVP addition.

III. EFFECT OF PROTEIN CONCENTRATES ON THE SHEAR VALUES OF SUMMER SAUSAGE

Table VI summarizes the analysis of variance for the effect of

TABLE IV

ANALYSIS OF VARIANCE FOR THE EFFECT OF PROTEIN CONCENTRATES ON THE AVAILABLE LYSINE CONTENT OF SUMMER SAUSAGE

Source	D.F.	Mean Square
Replication	1	0.298
Error A[1]	4	0.315
Treatment	7	1.799*
T x R	7	0.008
Error B[2]	28	0.567
Residual Error	48	0.532
Total	95	0.586

[1]Days within replication used to test replication.

[2]Treatment by day interaction within replication for testing treatment.

*Significant at the 0.01 level of probability.

TABLE V

EFFECT OF PROTEIN CONCENTRATES ON THE AVAILABLE LYSINE CONTENT[1] OF SUMMER SAUSAGE

Treatment[2]	Means[3,4]
FPC (4 percent)	3.17[a]
FPC (8 percent)	3.11[a]
MPC (4 percent)	2.59[abc]
MPC (8 percent)	2.66[abc]
TVP (4 percent)	2.20[bc]
TVP (8 percent)	2.08[c]
Control 1	2.83[ab]
Control 2	2.69[abc]
$S_{\overline{X}}$	0.218

[1]Available Lysine Content is reported as grams per 100 grams protein.

[2]FPC - fish protein concentrate
MPC - meat by-product protein concentrate
TVP - textured vegetable protein

[3]Means of 18 observations.

[4]Means within the column followed by the same letters are not significantly different at the 0.05 level of probability.

TABLE VI

ANALYSIS OF VARIANCE FOR THE EFFECT OF PROTEIN CONCENTRATES ON THE SHEAR VALUES[1] OF SUMMER SAUSAGE

Source	D.F.	Mean Square
Replication	1	3363.889*
Error A[2]	4	157.280**
Treatment	7	2713.889**
T x R	7	129.203*
Error B[3]	28	44.309**
Residual Error	96	21.045
Total	143	189.862

[1]Shear values were recorded as kilograms force required to shear the sausage sample.

[2]Days within replication used to test replication.

[3]Treatment by day interaction within replication for testing treatment.

*Significant at the 0.01 level of probability.

**Significant at the 0.05 level of probability.

protein concentrates on the shear values of summer sausage. There were significant differences in treatment, replication and the T x R interaction. Although the significant interaction between treatments and replication implies poor controls of the shear measurement, there are definite trends that can be noted among the treatment means in Table VII. Shear values for TVP added sausages were the same as the all meat controls.

Both controls and TVP added sausages were significantly more tender than those supplemented with FPC or MPC. The MPC added sausages at both 4 percent and 8 percent levels were significantly less tender than either the 4 ot 8 percent level of FPC added products. Comparing the differences between 4 and 8 percent levels of the three kinds of additives, sausages containing 8 percent was significantly less tender for MPC but no significance was detected between the 4 percent and 8 percent levels of FPC and TVP added sausages. These data suggest that there may be a difference between plant and animal protein in regard to their effect on palatability of sausages.

IV. EFFECT OF PROTEIN CONCENTRATES ON THE DOMINANT WAVELENGTH AND COLOR PURITY OF SUMMER SAUSAGE

The results of the effect of protein concentrates on dominant wavelength and color purity of summer sausages are tabulated in Table VIII. The summary of the analysis of variance is shown in Table IX. There were no significant difference in dominant wavelength among treatments, but a significant replicate difference was observed. The

TABLE VII

EFFECT OF PROTEIN CONCENTRATES ON THE SHEAR VALUES[1] OF SUMMER SAUSAGE

Treatment[2]	Means[3,4]
FPC (4 percent)	78.9[cd]
FPC (8 percent)	81.1[c]
MPC (4 percent)	91.8[b]
MPC (8 percent)	103.5[a]
TVP (4 percent)	71.8[de]
TVP (8 percent)	70.6[de]
Control 1	73.1[cde]
Control 2	67.4[e]
$S_{\overline{X}}$	2.678

[1]Shear values were recorded as kilograms force required to shear sample.

[2]FPC - fish protein concentrate
MPC - meat by-product protein concentrate
TVP - textured vegetable protein

[3]Means of 18 observations.

[4]Means within the column followed by the same letters are not significantly different at the 0.05 level of probability.

TABLE VIII

ANALYSIS OF VARIANCE FOR THE EFFECT OF PROTEIN CONCENTRATES ON THE DOMINANT WAVELENGTH AND COLOR PURITY OF SUMMER SAUSAGE

		Mean Squares	
Source	D.F.	Dominant Wavelength (nm)	Purity (Percent)
Replication	1	1013.361*	1.563
Error A[1]	4	65.660**	7.034*
Treatment	7	89.377	138.388**
T x R	7	53.504**	6.864
Error B[2]	28	4.390**	4.399*
Residual Error	96	1.966	2.395
Total	143	18.096	9.788

[1]Days within replication used to test replication.

[2]Treatment by day interaction within replication for testing treatment.

*Significant at the 0.01 level of probability.

**Significant at the 0.05 level of probability.

TABLE IX

EFFECT OF PROTEIN CONCENTRATES ON THE DOMINANT WAVELENGTH AND COLOR PURITY OF SUMMER SAUSAGE

Treatment[1]	Means[2,3] Wavelength (nm)	Means[2,3] Purity (Percent)
FPC (4 percent)	585.9[f]	29.7[c]
FPC (8 percent)	585.0[f]	32.1[b]
MPC (4 percent)	585.5[f]	31.7[b]
MPC (8 percent)	585.4[f]	35.6[a]
TVP (4 percent)	588.8[f]	29.1[cd]
TVP (8 percent)	587.1[f]	30.0[c]
Control 1	589.6[f]	27.9[de]
Control 2	590.7[f]	26.7[e]
$S_{\bar{X}}$	1.724	0.494

[1]FPC - fish protein concentrate
MPC - meat by-product protein concentrate
TVP - textured vegetable protein

[2]Means of 18 observations.

[3]Means within the column followed by the same letters are not significantly different at the 0.05 level of probability.

significance among replicates and the T x R interaction observed for dominant wavelength merely emphasizes the variation encountered when measuring products such as those in this study which do not have a uniform color surface. Large and small fat particles were scattered throuhout the sausage surface, the relative size of fat particles influenced the dominant wavelength. The variation observed in this study is common for course chopped products similar to those in this study. The dominant wavelength means among treatments shown in Table IX ranged from 585 to 590 nm. which indicate the color of the sausages was orange (Figure 2). Treatment means for color purity in Table IX indicate that 8 percent MPC added sausages were significantly darker in color than sausages containing other protein concentrates. This is not surprising since the MPC is known to possess higher myoglobin pigment than FPC and TVP. Sausages with 8 percent levels of FPC and MPC were respectively significantly darker than those with 4 percent levels, however, in the TVP added sausages the addition of 8 percent further lightened the sausage color. Both 4 and 8 percent level of TVP added sausages were lighter in color than sausages with other protein concentrates except the 4 percent level of FPC added sausages and controls. This is due to the replacement of myoglobin present in the beef and pork of this sausage formula with a low color contributor such as soy protein.

V. EFFECT OF PROTEIN CONCENTRATES ON THE ORGANOLEPTIC EVALUATION OF SUMMER SAUSAGE

The sausages containing protein additives were evaluated for

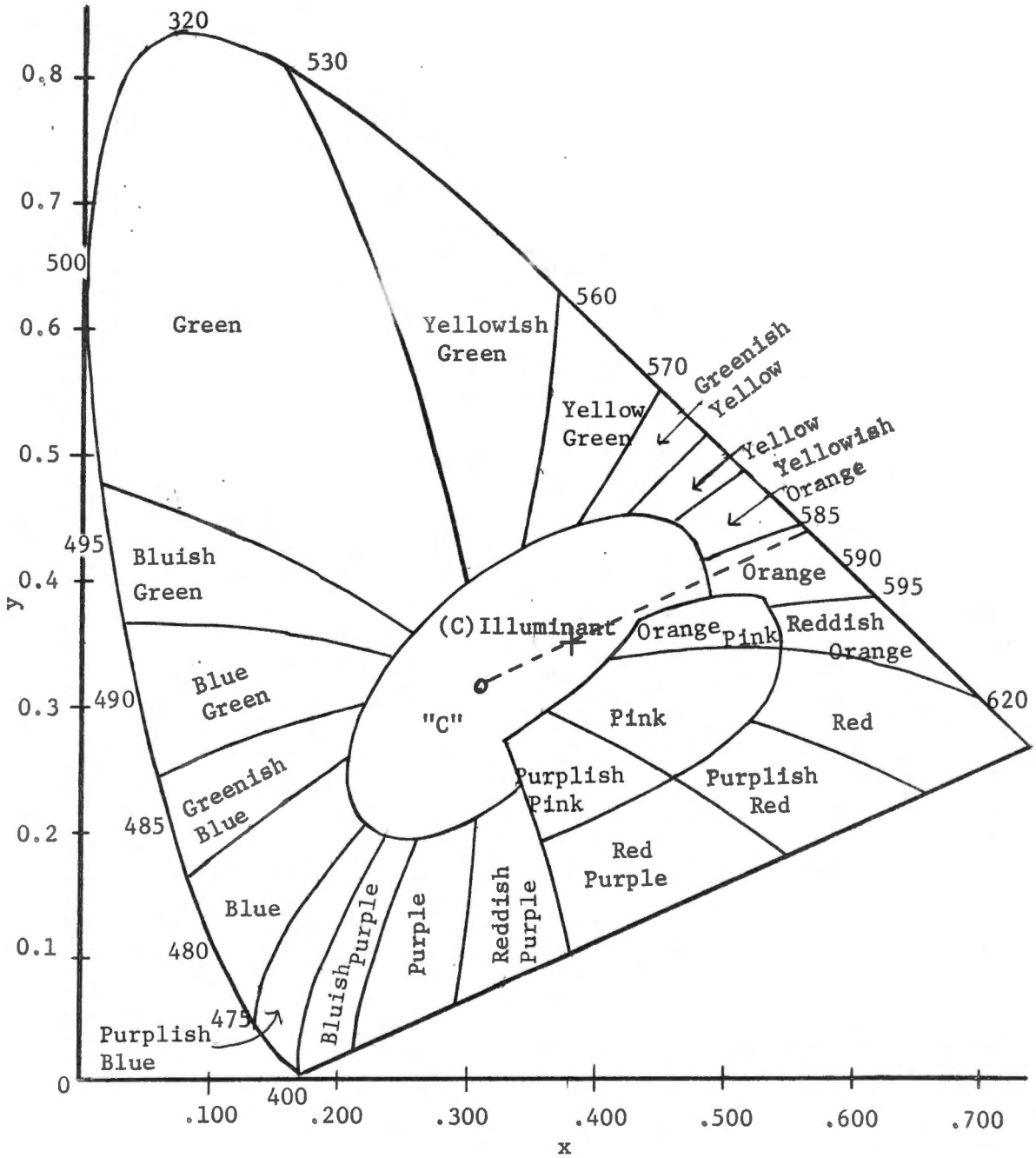

Figure 2. The (x,y)-chromaticity diagram of the Commission International de L'Eclairage (C.I.E.) system (18) showing the locus of dominant wavelength of sausage.

texture, flavor and appearance as they differed from the all meat control samples. The control sample was assigned a score of five. If the sausage containing a protein additive was judged inferior a score above five was assigned and if judged to be superior a score lower than five was given in Appendix C. The summary of the analysis of variance for the effect of adding protein concentrates on the sensory score of texture, flavor and appearance in summer sausage is presented in Table X. A significant treatment effect was observed for texture and appearance as they differed from the control samples, but flavor was not different. These results may be explained by the type of panel which was used to evaluate the sausage products. It was an untrained panel with no previous experience in detecting flavor differences of sausage products. So the flavor would be the most difficult to evaluate for a panel of this type. A significant interaction between treatment and replication was found for texture. Although a non-significant treatment effect was shown for flavor by the analysis of variance, the means in Table XI indicate that the panelists had less preference for the 4 and 8 percent level of FPC and the 8 percent level of MPC sausages. The 4 percent level of MPC and both levels of TVP sausages were very similar in flavor to the all meat control samples. Actually the low range in scores indicate that all samples with the exception of 8 percent level of FPC and MPC were acceptable.

As shown in Table X, a significant difference in texture between treatments was observed. Sausages containing 8 percent levels of FPC, MPC and TVP were scores less desirable than those with 4 percent levels.

TABLE X

ANALYSIS OF VARIANCE FOR THE EFFECT OF PROTEIN CONCENTRATES ON THE ORGANOLEPTIC EVALUATION OF SUMMER SAUSAGE

Source	D.F.	Mean Squares		
		Texture	Flavor	Appearance
Replication	1	33.152*	43.392*	0.117
Error A[1]	2	0.462	1.564	0.726
Treatment	6	30.194*	22.226	39.347**
T x R	6	5.719*	10.182*	10.217
Error B[2]	12	1.201	2.342	4.160
Residual Error	392	2.742	3.804	1.766
Total	419	3.195	4.244	2.485

[1]Days within replication used to test replication.

[2]Treatment by day interaction within replication for testing treatment.

*Significant at the 0.01 level of probability.

**Significant at the 0.05 level of probability.

TABLE XI

EFFECT OF PROTEIN CONCENTRATES ON THE ORGANOLEPTIC EVALUATION OF SUMMER SAUSAGE

Treatment[1]	Means[2,3,4]		
	Texture	Flavor	Appearance
FPC (4 percent)	4.97[bc]	6.00[f]	5.47[l]
FPC (8 percent)	6.03[ab]	6.95[f]	6.62[k]
MPC (4 percent)	5.65[bc]	5.50[f]	5.43[l]
MPC (8 percent)	6.72[a]	6.63[f]	7.30[k]
TVP (4 percent)	4.63[c]	5.23[f]	4.92[l]
TVP (8 percent)	5.15[bc]	5.78[f]	5.65[l]
Control 1	5.10[bc]	5.35[f]	5.56[l]
$S_{\bar{X}}$	0.309	0.412	0.264

[1]FPC - fish protein concentrate
MPC - meat by-product protein concentrate
TVP - textured vegetable protein

[2]Means of 60 observations.

[3]Means within the column followed by the same letters are not significantly different at the 0.05 level of probability.

[4]Scores for different tests found in Appendices C and D.

Sausages containing 8 percent of MPC was scored higher than all other sausages indicating that it was the most inferior compared to the control. The only sausages that were scored more acceptable in texture than the control were those with 4 percent FPC and TVP. The relationship between the square roots of mechanical shear values and sensory tenderness estimates is presented in Figure 3. A highly significant correlation coefficienty ($r = 0.84$) was observed. This situation was also found by Bailey et al. (7), Marsh et al. (29) and Burrill et al. (9).

There was a significant difference in appearance of the protein additive sausages compared to the control. The treatment means are presented in Table XI. The 8 percent levels of FPC and MPC added sausages received the highest difference scores and thus were evaluated the least desirable in appearance of all sausages. There was no significant difference among the other samples. The 8 percent levels of FPC and MPC added sausages were very dark in color and received the highest or darkest purity scores when subjected to the color eye instrument.

The summary of the analysis of variance for the effect of protein concentrates on the overall sensory acceptability of summer sausage is shown in Table XII. This analysis revealed a highly significant treatment effect of varying levels of the three kinds of protein additives. The test for significance among treatment means is shown in Table XIII. These data suggest that the taste panel preferred the all meat controls and rated sausages with 8 percent level of FPC lower in overall acceptability than those containing other protein concentrates. All meat control sausages were significantly more acceptable than those containing

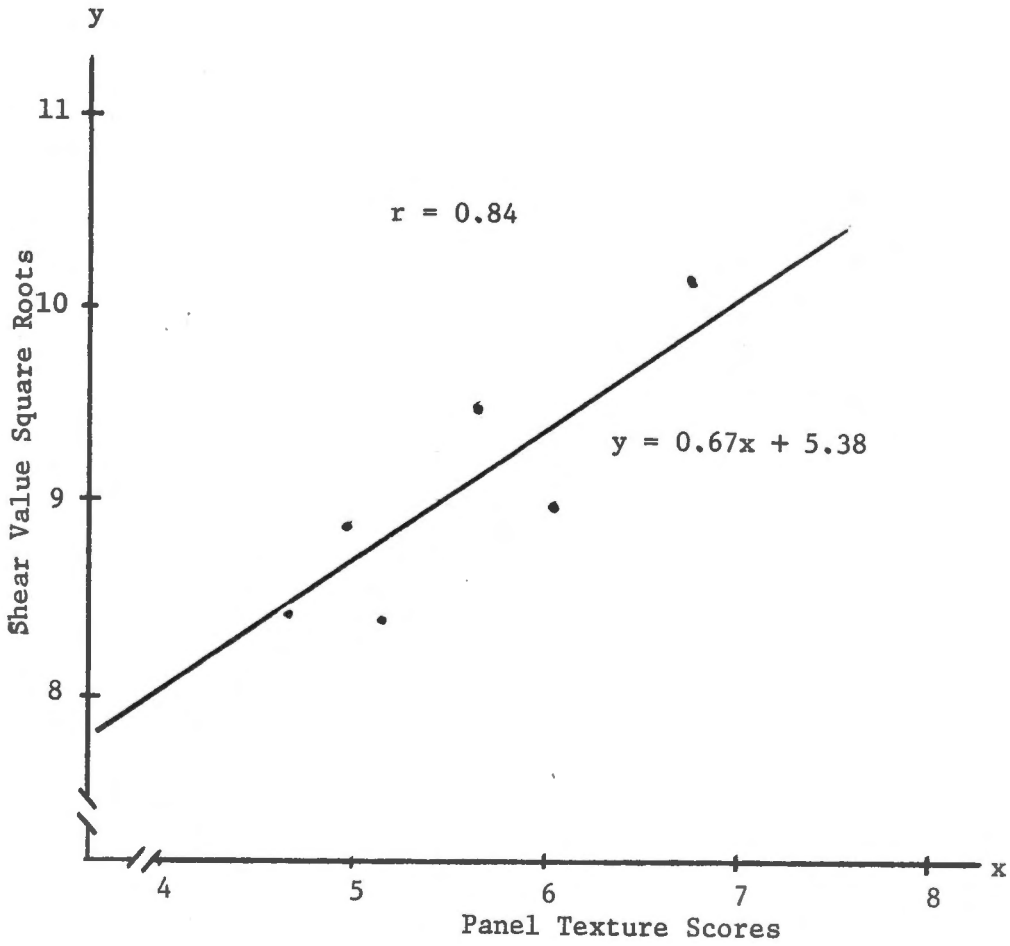

Figure 3. Relationship between panel texture scores and shear value square roots.

TABLE XII

ANALYSIS OF VARIANCE FOR THE EFFECT OF PROTEIN CONCENTRATES ON THE OVERALL ACCEPTABILITY OF SUMMER SAUSAGE

Source	D.F.	Mean Square
Replication	1	0.169
Error A[1]	2	4.427
Treatment	7	68.809**
T x R	7	6.954
Error B[2]	14	5.108
Residual Error	448	3.476
Total	479	4.526

[1]Days within replication used to test replication.

[2]Treatment by day interaction within replication for testing treatment.

**Significant at the 0.05 level of probability.

TABLE XIII

EFFECT OF PROTEIN CONCENTRATES ON THE OVERALL ACCEPTABILITY OF SUMMER SAUSAGE

Treatment[1]	Means[2,3,4]
FPC (4 percent)	4.67[ab]
FPC (8 percent)	5.82[a]
MPC (4 percent)	4.12[bc]
MPC (8 percent)	5.70[a]
TVP (4 percent)	3.85[bc]
TVP (8 percent)	4.72[ab]
Control 1	3.25[cd]
Control 2	2.82[d]
$S_{\overline{X}}$	0.292

[1]FPC - fish protein concentrate
MPC - meat by-product protein concentrate
TVP - textured vegetable protein

[2]Means of 60 observations.

[3]Means within the column followed by the same letters are not significantly different at the 0.05 level of probability.

[4]Scores for overall acceptability found in Appendix B.

4 and 8 percent level of MPC, 8 percent level of TVP and 4, 8 percent level of FPC. It should be pointed out, however, that only 8 percent level of FPC and 8 percent level of MPC added sausages were given a score of 5 or higher. A score of five implying a neither like or dislike rating by the panel menbers is shown in the Appendix B.

CHAPTER V

SUMMARY

This study was designed to compare protein added sausages in chemical composition, physical quality and organoleptic acceptability. Three kinds, fish protein concentrate (FPC), meat protein concentrate (MPC) and soy protein concentrate (SPC) and two levels (4 percent and 8 percent) of protein concentrates were added to the summer sausages for this study.

Significant effects among treatment were found in all the quality attributes except dominant wavelength and flavor. In general, the increase of protein concentrates caused decreased fat and an increased protein content. TVP was the only protein additive which caused a decrease in available lysine content when the addition level was over 4 percent. At the 4 and 8 percent levels, protein concentrates did not affect the dominant wavelength, but did influence the color purity. Greater force was needed to shear the sausages which were supplemented by MPC or FPC. No difference in flavor evaluation was found among treatments. At the 4 percent level of protein concentrate, sausages containing FPC or TVP were superior to the all-meat controls in texture evaluation. Only 8 percent levels of FPC and MPC in sausages showed a more undesirable score than the other treatments. All the protein concentrate added sausages had lower acceptability than the all-meat control sausages, although the 4 percent levels of FPC or MPC and both 4, 8 percent levels of TVP sausages were readily acceptable by the panel.

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APPENDIX

APPENDIX A

STATISTICAL MODEL

A. Statistical Model used for the Analysis of Variance:

$$Y = \mu + R_i + D_{k(i)} + T_j + RT_{ij} + TD_{jk(i)} + \varepsilon_{l(ijk)}$$

B. Sources of Variation for Analysis of Variance:

Replication

Error A--Days within replication. $(D_{k(k)})$

Treatment

T x R

Error B--Interaction of treatments and days within replication for testing treatment. $TD_{jk(i)}$

Residual Error--Measurement error.

Total

C. Expected Mean Squares for each Source of Variation:*

Source	E.M.S.
Replication--R_i	$\sigma^2 + 16\sigma^2_D + 32\sigma^2_R$
Error A--$D_{k(i)}$	$\sigma^2 + 16\sigma^2_D$
Treatment--T_j	$\sigma^2 + 2\sigma^2_{DT} + 4\sigma^2_{RT} + 8\sigma^2_T$
T x R--RT_{ij}	$\sigma^2 + 2\sigma^2_{DT} + 4\sigma^2_{RT}$
Error B--$TD_{j(jk)}$	$\sigma^2 + 2\sigma^2_{DT}$
Residual Error $\varepsilon_{l(ijk)}$	σ^2

*Except for taste panel.

APPENDIX B

PREFERENCE TEST

Taster_____ Date_____

Evaluate these samples of sausage for overall acceptability. Taste test each one. Use the appropriate score to show your evaluation by circling at the point that best describes your feeling about the sample.

CODE								
Like Extremely	1	1	1	1	1	1	1	1
Like Very Much	2	2	2	2	2	2	2	2
Like Moderately	3	3	3	3	3	3	3	3
Like Slightly	4	4	4	4	4	4	4	4
Neither Like Nor Dislike	5	5	5	5	5	5	5	5
Dislike Slightly	6	6	6	6	6	6	6	6
Dislike Moderately	7	7	7	7	7	7	7	7
Dislike Very Much	8	8	8	8	8	8	8	8
Dislike Extremely	9	9	9	9	9	9	9	9
Comments:								

APPENDIX C

DIFFERENCE TEST

Taster_____ Date_____

Questionnaire:

You are receiving samples of sausage to compare for_____ You have been given a reference sample (R), to which you are to compare each sample. Test each sample, show whether it is better than, comparable to, or inferior to the reference. Then mark the amount of difference that exists.

SAMPLE NUMBER	____	____	____	____	____	____	____
BETTER THAN R	____	____	____	____	____	____	____
EQUAL TO R	____	____	____	____	____	____	____
INFERIOR TO R	____	____	____	____	____	____	____

AMOUNT OF DIFFERENCE:

NONE	____	____	____	____	____	____	____
SLIGHT	____	____	____	____	____	____	____
MODERATE	____	____	____	____	____	____	____
MUCH	____	____	____	____	____	____	____
EXTREME	____	____	____	____	____	____	____

COMMENTS: Any comments you may have about the_____of the samples may be made here:

APPENDIX D

SCALE FOR DIFFERENT TESTS

1 = Extremely better than R

2 = Much better than R

3 = Moderately better than R

4 = Slightly better than R

5 = Equal to R (No difference)

6 = Slightly inferior to R

7 = Moderately inferior to R

8 = Much inferior to R

9 = Extremely inferior to R

TABLE XIV

THE EFFECT OF PROTEIN CONCENTRATES ON THE CHEMICAL COMPOSITION AND PHYSICAL QUALITY FO SUMMER SAUSAGES

Replication	Treatment	Protein[1] %(Nx6.25)	Fat[1] %	Moisture[1] %	Available[1] Lysine gm/100 gm Protein	Purity[2] %	Dominant[2] Wavelength Length nm	Shear[2] Force kg force
	4% FPC	20.8	21.8	49.8	3.2	29.0	588.4	87.7
	8% FPC	22.7	20.9	49.2	3.2	31.9	584.2	88.0
	4% MPC	22.0	21.9	49.5	2.7	32.3	588.0	98.1
	8% MPC	23.8	20.7	48.7	2.7	36.8	586.3	103.8
I	4% TVP	21.0	20.6	51.5	2.2	28.7	593.6	75.7
	8% TVP	21.7	19.6	52.2	2.2	30.1	590.3	76.4
	Control 1	19.4	22.5	52.2	2.9	27.7	593.8	77.5
	Control 2	18.8	22.8	54.0	2.8	27.0	594.2	69.7
	4% FPC	20.6	22.0	51.0	3.1	30.3	583.3	70.2
	8% FPC	23.6	22.2	47.7	3.0	32.3	585.]	74.2
	4% MPC	21.9	22.1	50.7	2.5	31.0	583.0	85.6
II	8% MPC	25.4	20.5	49.0	2.6	34.3	584.1	103.1
	4% TVP	20.9	21.8	51.0	2.2	29.4	584.0	67.8
	8% TVP	21.2	20.7	51.5	2.0	29.9	583.8	64.8
	Control 1	19.4	23.5	52.0	2.8	28.1	585.4	68.8
	Control 2	19.0	24.1	51.2	2.6	26.3	587.2	65.1

[1]Variable means for replicate I and replicate II: each value is the mean of 6 observations.

[2]Variable means for replicate I and replicate II: each value is the mean of 9 observations.

TABLE XV

THE EFFECT OF PROTEIN CONCENTRATES ON ORGANLEPTIC EVALUATION OF SUMMER SAUSAGES

Replication	Treatment	Difference Test[1,2]			Preference Test[1,3]
		Texture	Flavor	Appearance	Overall Acceptability
I	4% FPC	5.6	6.0	5.4	4.3
	8% FPC	6.3	6.9	6.2	5.6
	4% MPC	5.9	5.7	5.9	4.2
	8% MPC	7.1	7.3	7.4	4.9
	4% TVP	5.5	6.1	5.4	4.1
	8% TVP	5.5	6.8	5.5	5.6
	Control	4.8	5.3	5.9	3.6
II	4% FPC	5.0	6.0	5.5	4.7
	8% FPC	5.9	7.2	6.6	6.0
	4% MPC	5.7	5.9	5.7	4.2
	8% MPC	6.9	6.8	7.3	6.4
	4% TVP	4.6	5.0	5.1	4.0
	8% TVP	5.2	5.6	5.6	4.2
	Control	5.0	5.2	5.0	3.2

[1]Each value is the mean of 30 observations.

[2]Scores for different tests found in Appendices C and D.

[3]Scores for overall acceptability found in Appendix B.

VITA

Hwa-Lien Lee was born in Kwantung Province, China on November 12, 1942. He attended elementary school and high school at Kelung School, Kelung City, Taiwan, and graduated on June 20, 1960. He entered Chung Hsing University in Taichung, Taiwan, in 1963. In May of 1967, he received a Bachelor of Science degree in Agronomy.

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