Emulsion Characteristics and Processing Feasibility of Sausage Products Incorporating Unconventional Protein Sources

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There has been recent interest in developing food uses for by-products obtained from the food processing industry. Some by-products have been considered as solid or liquid wastes, while others have generated a little income as human food. The success of isolated soy protein in emulsion sausage items, due to its superior water and fat binding properties, suggests this avenue of utilization for other by-product protein sources. (Frank and Circle, 1959 and Pearson et al., 1965).

To reestablish a market for discarded layers, the poultry industry has studied the feasibility of using boneless chicken in sausage emulsions. (Hudspeth and May, 1967). Baker et al. (1969) determined, by making chicken emulsion products using levels of beef, pork and chicken fat, that 30% fat yielded the most desirable product. Baker (1970) determined that pH was also an important variable in developing a firm chicken emulsion product.

Edible by-products from the visceral tract have received limited use in low-cost sausage formulations. In their natural form, these visceral by-products are nutritious but variable in palatability. Levin (1970a and 1970b) developed an azeotropic distillation procedure using ethylene dichloride and isopropanol to produce a meat protein concentrate from liver, lung, spleen, heart, stomach, kidney, blood and bone. He also reported that this meat protein concentrate was 85-90% protein and had a biological value of 70% that of casein.

Dairy by-products such as non-fat dry milk, calcium reduced non-fat dry milk and sodium caseinate are used in sausage emulsions because of their ability to bind and emulsify fat (Pearson et al., 1965 and Inklaar and Fortuin, 1969). The utilization of cottage cheese whey has recently been studied because 73% of the nutrients of non-fat dry milk have been discarded in this waste product. Carboxymethyl cellulose, a hydrocolloid stabilizer capable of precipitating whey protein was studied to develop a procedure for salvaging whey protein from the cottage cheese wastes (Hidalgo and Hansen, 1969). By adding carboxymethyl cellulose and lowering the pH of the whey to 3.2-4.0, the protein may be precipitated and then separated. This whey protein complex can then be dried using a freeze drier or spray drier.

This study was undertaken to compare the emulsion characteristics and product acceptability of whey protein, visceral by-product "meat powder", boneless chicken and soy-protein concentrate with those of beef and pork when used as protein sources in sausage emulsions.

Procedures

The protein sources chosen for the study of emulsion characteristics included: (1) beef (boneless standard grade chuck, (2) pork (boneless shoulders), (3) commercially deboned frozen chicken (4) whey protein (freeze dried), produced using the carboxymethyl cellulose procedure of Hidalgo and Hansen (1969) by the Ohio State University Department of Food Science and Nutrition, (5) isolated soy proteinate (Promine D), (6) "meat powder" (meat by-product protein concentrate) obtained through the courtesy of Dr. Ezra Levin of the Viobin Corporation, Monticello, Illinois. The meat powder components were blood, trachea, lungs, esophagus, stomach, small and large intestines, bladder, heart, liver and kidneys extracted by the procedure of Levin (1970b).

The protein sources were subjected to proximate analysis (protein, moisture, ether extract and ash) as outlined by A.O.A.C. (1965). Determination of pH followed the procedure of Ockerman (1971).

Emulsifying capacity (reported as either ml of fat per g of sample or ml of fat per g of protein) was determined using the method of Swift et al. (1961) with modifications by Potter, (1971). This capacity was determined using beef fat, pork fat and cottonseed oil and was completed at three pH values (5.0, 8.0 and the normal pH of the protein source).

Stability of the emulsion (% of fat lost) was evaluated for the six protein sources. Each was combined with three fat sources at levels of 15%, 30%, 45% and 60% fat, using the procedures of Inklaar and Fortuin (1969) and Potter (1971).

To evaluate more closely the emulsion characteristics responsible for stability problems, a slide staining procedure for an emulsion smear was accomplished. The smearing technique was similar to that for blood as described by Hepler (1957). Following the smearing preparation of the slide, refrigeration at 3.3°C for 24 hours and washing with 70% alcohol, the slide was stained twice. The first stain (fat isolation) contained 0.5 g Sudan IV, 50 ml acetone and 50 ml 70% alcohol. After one minute the stain was washed with 50% alcohol and then distilled water. The second stain (protein fixation) consisted of 1.0 g bromophenol blue and 9 ml distilled water and was left on for three minutes before rinsing with distilled water containing a few drops of ammonium hydroxide. Photomicrographs of the slides were made.

Following these preliminary emulsion studies, two series of bologna type products were made. The first series of products were replicated three times and included a comparison of four protein sources using both beef and pork fat. The protein sources were: (1) boneless shank from choice rounds, (2) boneless shank plus meat powder (10% of the recipe), (3) whey protein, and (4) isolated soy proteinate. The recipes included protein source, fat type (20-25% level), ice water, NaCl, $NaNO_3$, $NaNO_2$ and a commercial seasoning mix. All items were added on the same percentage basis to all products. Processing times and temperatures were constant. Emulsions did not exceed 15.6°C during chopping. The emulsions were stuffed into cellulosic bologna casings and cooked in the Atmos smokehouse to a constant internal temperature of 68°C.

The second series compared seven products combining beef and either meat powder or whey protein in varying amounts as the protein block. The seven products were: (1) beef (boneless, choice chucks), as a control, (2) beef plus whey protein at levels of 70%, 30% and 3-1/2%, and (3) beef plus meat powder at levels of 70%, 5% and 1%. No added fat was included in the formulation. The other ingredients and processing schedule remained as previously outlined. All emulsion products were evaluated as to composition and palatability.

Results and Discussion

Table 1 contains the results of the pH and proximate analysis determination for the six protein sources. Data for beef, pork and chicken are within the ranges reported by Ockerman (1971). The isolated soy proteinate analysis agreed with the previous reports. Meat powder data agreed with that reported by Levin (1970a). The missing 9.4% of meat powder includes in part carbohydrate and a 12 ppm. residue of the ethylene dichloride solvent as reported by Levin (1972). The 74% protein content of the meat powder compared favorably with the high protein percentage of the isolated soy proteinate.

The whey protein percentages were complicated by a residue of carboxymethyl cellulose, which was not determined in the analysis. Except for a 3% higher moisture content, and thus a 3% lower protein content in the whey protein data they agreed with the report of Hansen (1971).

TABLE 1. PROXIMATE ANALYSIS AND pH FOR SELECTED PROTEIN SOURCES

Protein Source	Protein %	Fat, %	Water, %	Ash, %	pH
Beef	19.5	10.8	68.5	1.1	5.8
Pork	19.2	6.2	73.3	1.3	5.8
Chicken	12.5	20.6	66.2	0.7	5.8
Meat Powder[1]	74.0	3.5	6.8	7.3	5.8
Soy[2]	88.3	1.2	6.3	4.2	6.6
Whey[3]	56.9	1.6	9.2	1.2	4.8

[1] Freeze dried sample not analyzed for carbohydrate and containing "residual" of 12 ppm ethylene dichloride solvent.

[2] Isolated soy proteinate (Promine D). Worthington Foods, Worthington, Ohio.

[3] Whey protein includes residual carboxymethyl cellulose, a polysaccharide used to precipitate the protein.

Table 2 presents the emulsifying capacity (ml of fat per g of sample) and table 3 presents the emulsifying efficiency (ml of fat per g of protein) of the protein sources. Emulsifying capacity was affected significantly by fat source (P<.01). With pH and protein effects absorbed, more beef fat was emulsified per g of sample than either pork fat or cotton seed oil.

TABLE 2
EMULSIFYING CAPACITY OF PROTEIN SOURCES AS INFLUENCED BY pH AND FAT SOURCE

pH[1]	5.0			N[2]			8.0		
Fat Source[3]	Beef	Pork	Cottonseed	Beef	Pork	Cottonseed	Beef	Pork	Cottonseed
Emulsion Cap.	ml fat/g of sample								
Protein Source									
Beef	46.4	52.8	50.0	64.0	66.1	56.9	92.0	79.6	90.0
Pork	----	----	59.1	----	----	60.5	----	----	100.0
Chicken	30.0	43.2	81.5	52.8	46.8	67.4	53.6	51.6	87.0
Meat Powder	37.2	36.8	45.0	46.0	42.8	37.8	96.8	80.0	72.5
Soy	130.6	123.8	75.0	171.5	159.2	50.0	217.7	206.8	111.8
Whey	191.8	160.5	108.2	166.0	148.3	110.5	421.8	408.2	131.0

[1] pH effects significant (P<.01).

[2] N = Natural pH of the protein source as presented in Table 1.

[3] Fat source significant (P<.01).

TABLE 3
EMULSIFYING EFFICIENCY OF PROTEIN SOURCES AS INFLUENCED BY pH AND FAT SOURCE

pH[1]	5.0			N[2]			8.0		
Fat Source	Beef	Pork	Cottonseed	Beef	Pork	Cottonseed	Beef	Pork	Cottonseed
Emulsion Cap.	ml fat/mg of protein								
Protein Source									
Beef	0.24	0.28	0.20	0.34	0.35	0.23	0.48	0.42	0.36
Pork	----	----	0.25	----	----	0.25	----	----	0.42
Chicken	0.25	0.43	0.44	0.36	0.38	0.43	0.48	0.40	0.51
Meat Powder	0.05	0.05	0.17	0.06	0.06	0.14	0.13	0.10	0.27
Soy	0.14	0.14	0.23	0.19	0.18	0.16	0.25	0.23	0.35
Whey	0.36	0.30	0.55	0.31	0.28	0.55	0.79	0.76	0.66

[1] pH effects significant (P<.01).

[2] N = Natural pH of the protein source as presented in Table 1.

Meyer et al. (1964) reported that the type of fat altered the emulsion stability and Townsend et al. (1968) postulated that fats with higher melting points were more stable in emulsions.

The significant (P<.01) effect of increasing pH on emulsifying capacity and efficiency agreed with the data of Inklaar and Fortuin (1969). Johnson and Hendrickson (1970) postulated that the increase in pH would increase the solubility of the protein and thus more protein would be available to encapsulate the fat globules.

The emulsifying capacity and efficiency of beef in this study agreed with the results obtained by Graner et al. (1969). The inverse relationship between protein content (Table 1) and emulsifying efficiency (Table 3) in general agreed with the reports of Swift et al. (1961), and Ivey et al. (1970). Ivey et al. (1970) postulated that as the protein decreased in concentration, a greater degree of unfolding occurred in the protein helix which brought about a greater degree of molecular orientation on the fat globule surface. The emulsifying efficiency of whey protein was the exception to this trend, but the presence of carboxymethyl cellulose confounds these results. A pH of 8.0 was most favorable for the efficiency of whey protein. The whey protein showed great promise for emulsion meat products.

Information concerning the stability of emulsions expressed as percent of the fat lost is presented in Table 4. Fat type did not have a significant effect on emulsion stability although, at high fat levels, emulsions with cottonseed oil appeared to be more stable when made with meat powder, whey protein or isolated soy proteinate. These data did not agree with the reports of Meyer et al. (1964) and Townsend et al. (1968) which state that the low melting fats produce less stable emulsions.

The most stable emulsions were those produced using beef or pork. This was largely due to the quantity of the salt soluble protein, myosin, present in these protein sources (Fukazawa et al., 1961a). Meat Powder did not form stable emulsions at any fat level. Whey protein performed well up to the 45% fat level. There was no significant difference in stability when using beef, chicken or isolated soy proteinate at the 15, 30, 45 percent fat levels. It is interesting to note that apparently when the protein has reached its limit for encapsulation, most of the fat breaks out of its protein coating (Potter, 1971).

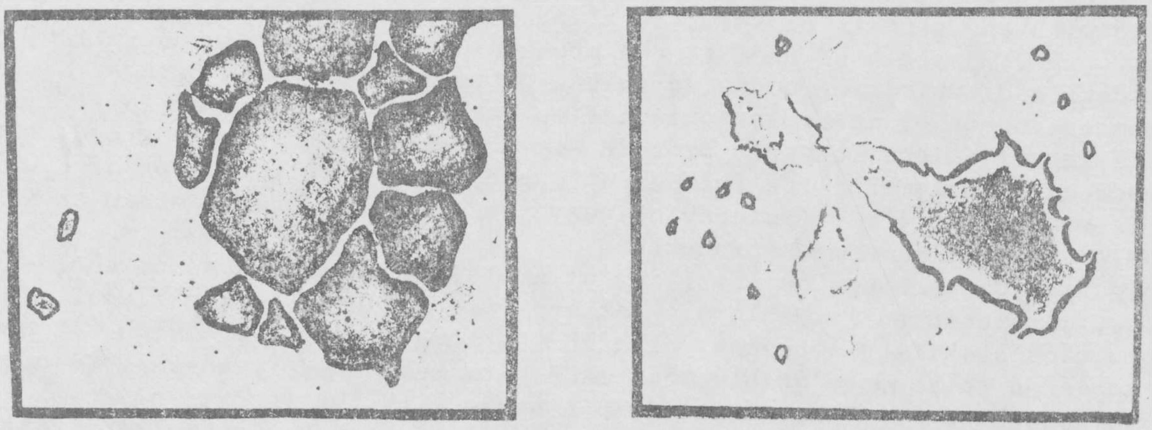
TABLE 4. EMULSION STABILITY (% FAT LOST) FOR PROTEIN SOURCES

Fat Source	Fat Level[1]	Protein Source					
		Beef	Pork	Chicken	Meat Powder	Whey	Soy
Beef	15	0	--	0	92.2	0	0
Pork	15	0	--	0	75.6	0	0
Cottonseed	15	0	0	0	75.0	0	2.0
Beef	30	0	--	0	84.5	0	0
Pork	30	0	--	5.6	95.6	0	0
Cottonseed	30	0	1.0	1.0	76.0	8.0	1.0
Beef	45	0	--	6.0	97.8	82.3	0
Pork	45	0	--	6.0	98.9	97.4	0
Cottonseed	45	1.0	1.0	7.0	80.0	52.0	8.0
Beef	60	12.8	--	81.1	93.4	87.8	98.9
Pork	60	15.5	--	69.9	95.6	95.0	95.5
Cottonseed	60	17.0	18.0	50.0	87.0	55.0	82.0

1 Percent added fat effects significant (P<.01)

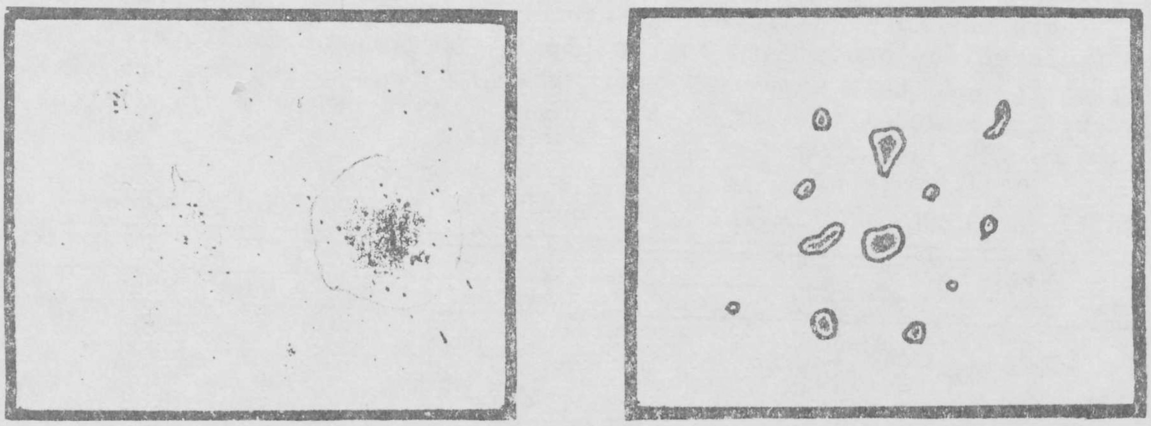
Examination of the photomicrographs provided some insight into the reasons for stability problems. Figure 1A presents a stable beef emulsion at the 45% fat level and Figure 1B presents a single, irregular shaped, fat globule breaking out of its protein coating as was the case with the beef emulsion at the 60% fat level. This latter emulsion gave up 12.8% of its fat. The more stable emulsion showed a much thicker coating of protein over the fat globule. This agreed with the report of Hansen (1960) which stated that photomicrographs of stable emulsions displayed thicker coatings of salt soluble proteins.

Figure 1. Diagram of photomicrographs of stable and unstable beef emulsions.



A. Stable Beef Emulsion: 45% Fat   B. Unstable Beef Emulsion: 60% Fat

Figure 2. Diagram of photomicrographs of meat powder and whey protein emulsions at the 45% fat level.



A. Meat powder with 45% fat.   B. Whey protein with 45% fat.

Figure 2A represents an emulsion made with meat powder incorporating 45% pork fat. This emulsion as indicated in Table 4 lost 98.9% of its fat. Note the little, if any, protein coating on the irregularly shaped rupturing fat globules. Figure 2B, by contrast, shows an emulsion made with whey protein. The evenly dispersed, regular fat globules are coated by a uniform protein layer. This emulsion's stability was represented by the loss of 7% of its fat. It is the opinion of these authors the staining procedure and slide examination offers a 24 hr. emulsion quality control check.

Composition, appearance and palatability data for bologna type emulsion products made with beef, beef plus 10% meat powder, whey protein and isolated soy proteinate using either beef or pork fat are presented in Table 5. This initial study resulted in significantly ($P<.05$) lower reflectance values (darker color) for products made with the yellower beef fat. The products made with pork fat were significantly ($P<.05$) lower in percent ether extract and higher in percent of protein. Significant effects of protein source on color, texture, firmness, flavor and juiciness are illustrated in Table 5. Color of the 10% meat powder-beef product was judged less acceptable than the beef product because of its darkness, while isolated soy protein and whey protein produced an undesirable light color. Very soft, juicy and poorly textured products were produced when using the meat powder and whey products. The meat powder in this study contained pancreas and it was suggested that wetting of this substance during initial emulsification could have activated enzymes thus contributing to the problem (Levin, 1972). Later production of meat powder did not contain pancreas extract and product firmness improved.

Products made with both whey and isolated soy proteinate produced a bland to slightly objectionable off-flavor, while products containing 10% meat powder possessed a very strong off-flavor. The stronger flavor found associated with the isolated soy proteinate has previously been reported by Frank and Circle (1959).

TABLE 5. COMPOSITION, APPEARANCE AND EMULSION PRODUCT PALATABILITY

Fat Source[1]	Beef				Pork			
Protein Source	Beef	Beef + Meat Powder[2]	Whey	Soy	Beef	Beef + Meat Powder[2]	Whey	Soy
Protein, %	13.1^{a}	15.6^{b}	6.1^{c}	15.8^{b}	14.8^{a}	16.3^{b}	6.2^{c}	16.3^{b}
Moisture, %	61.4^{a}	56.9^{b}	58.6^{b}	53.3^{d}	62.8^{a}	58.5^{b}	64.9^{c}	52.7^{d}
Ether Extract,%	21.7^{a,b}	24.2^{c,d}	26.8^{e}	25.2^{d,e}	20.1^{a}	22.0^{a,b}	22.7^{b,c}	26.9^{e}
Reflectance[3]	31.8^{a}	27.2^{b}	61.2^{c}	56.0^{d}	32.6^{a}	31.5^{a}	69.5^{e}	57.2^{d}
Color[4]	6.9^{a}	4.2^{b}	1.9^{c}	2.3^{d}	7.3^{a}	3.8^{b}	1.6^{c}	2.1^{d}
Texture[4]	5.7^{a}	2.6^{b}	2.0^{b}	3.8^{c}	5.8^{a}	2.2^{b}	2.6^{b}	4.3^{c}
Firmness[4]	7.3^{a}	1.8^{b}	1.5^{b}	4.2^{c}	7.4^{a}	1.4^{b}	1.5^{b}	5.0^{c}
Flavor[4]	6.7^{a}	1.7^{b}	2.9^{c}	2.4^{c}	6.6^{a}	1.5^{b}	2.8^{c}	2.6^{c}
Juiciness[4]	6.3^{a}	2.7^{b}	2.8^{b}	3.3^{c}	6.4^{a}	2.5^{b}	2.8^{b}	3.5^{c}

a,b,c,d,e Means with different superscripts are significantly different.

1 Fat source effects were significant ($P<.05$) for composition and reflectance only.

2 10% of the recipe was meat powder.

3 Readings at 570 mμ.

4 1 = Unacceptable; 10 = Excellent for bologna color, texture, firmness, flavor or juiciness.

The appearance, palatability and product acceptability of emulsion products made with beef in combination with whey protein or meat powder as compared with beef bologna are presented in Table 6. The color of beef plus whey protein products were acceptable when whey protein represented as high as 30% of the protein block used in the emulsion. All products incorporating whey were more tender than beef bologna, perhaps to a fault. The use of 3.5% whey protein in the protein block produced the most acceptable product with flavors equal to that of the beef bologna. The emulsion characteristics, protein cost and product acceptability at the 3.5% level should suggest that whey protein has a future in sausage emulsions.

TABLE 6. APPEARANCE, PALATABILITY AND EMULSION PRODUCT ACCEPTABILITY

Protein Source	Beef	Beef + Whey			Beef + Meat Powder		
% of protein block	100	70	30	3.5	70	5	1
Appearance[1]							
Color	7.8[a]	3.8[b]	7.0[a]	7.8[a]	4.3[b]	6.7[a]	7.0[a]
Palatability							
Tenderness[2]	7.7[a]	9.0[b]	9.0[b]	8.9[b]	7.5[a]	7.3[a]	7.2[a]
Bologna flavor[3]	7.5[a]	2.1[b]	5.7[c]	6.8[a]	3.3[b]	6.8[a]	7.0[a]
Off flavor[4]	9.0[a]	4.7[b]	7.3[c]	8.4[a,c]	4.8[b]	6.1[c]	7.9[a]
Acceptability[5]	7.7[a]	3.1[b]	5.0[c]	7.6[a]	3.8[b]	6.3[a]	8.0[a]

a,b,c, Means with different superscripts are significantly different ($P<.05$).
1 1 = Unacceptable; 10 = very acceptable bologna color.
2 1 = very tough; 10 = very tender.
3 1 = lacking bologna flavor; 10 = very full bologna flavor.
4 1 = pronounced off flavor; 10 = no off flavor.
5 1 = very poor; 10 = very good acceptability as a bologna type product.

Meat powder, even at concentrations of 5% of the meat block, is effective at providing a slightly darker but acceptable bologna color. This could be an asset in the future. Tenderness, bologna flavor and overall product acceptability were good when meat powder was used as 5 or 1% of the meat block. Some off-flavors still persisted at the 5% incorporation level. The color benefits and product acceptability when meat powder is added as 1-5% of the protein block are reinforced by cost figures. Levin (1972) reported that the projected price for protein would be twenty-five cents per pound.

Processing experience would suggest that both meat powder and whey protein should be added to the emulsion in dry form because reconstitution to 70% moisture created texture problems in the finished product.

BIBLIOGRAPHY

A.O.A.C. 1965. Official Methods of Analysis (10th ed.) Association of Official Agricultural Chemists. Washington, D. C.

Baker, R. C., J. C. Darfler and D. V. Vadehra. 1969. Type and level of fat and amount of protein and their effect on the quality of chicken frankfurters. Food Technol. 23:808.

Baker, R. C., J. C. Darfler and D. V. Vadehra. 1970. Effect of pH on the quality of chicken franks. Food Sci. 35:1070.

Frank, S. S. and S. J. Circle. 1959. The use of isolated soy protein for non-meat, stimulated sausage products frankfurter and bologna types. Food Technol. 13:307.

Fukazawa, T., Y. Hashimoto and T. Yasui. 1961a. Effect of some proteins on the binding quality of an experimental sausage. J. Food Sci. 26:541.

Graner, Murilo, V. R. Cahill and H. W. Ockerman. 1969. The emulsifying capacity of bovine muscle tissue as related to time post mortem and microbial contamination. Food Techn. 23:12.

Hansen, L. J. 1960. Emulsion formation in finely comminuted sausage. Food Technol. 14:565.

Hansen, P. M. T. 1971. Personal Communication.

Hepler, O. E. 1949. Preparation of blood smear. Manual of Clinical Laboratory Methods (4th ed.) Charles C. Thomas. Springfield, Illinois.

Hildalgo, Jaime and P. M. T. Hansen. 1969. Interactions between food stabilizers and β - lactoglobulin. J. Agr. Food Chem. 17:5.

Hudspeth, J. P. and K. N. May. 1967. A study of the emulsifying capacity of salt soluble proteins of poultry meat. Food Technol. 21:141.

Inklaar, P. A. and J. Fortuin. 1969. Determining the emulsifying and emulsion stabilizing capacity of protein meat additives. Food Technol. 23:103.

Ivey, F. J., N. B. Webb and V. A. Jones. 1970. The effect of disperse phase droplet size and interfacial film thickness on the emulsifying capacity and stability of meat emulsions. Food Technol. 24:1279.

Johnson, R. G. and R. L. Henrickson. 1970. Effect of treatment of pre- and post-rigor porcine muscles with low sodium chloride concentration on the subsequent extractability of proteins. J. Food Sci. 35:268.

Levin, E. 1970a. Conversion of meat by-products into edible meat protein concentrate powder. Proceedings of Meat Industry Research Conf.

Levin, E. 1970b. MPC (meat protein concentrate) + edible fat. Food Technol. 24:19.

Levin, E. 1972. Personal Communication with Dr. R. F. Plimpton.

Meyer, J. A., W. L. Brown, N. E. Giltner and J. R. Guinn. 1964. Effect of emulsifiers on sausage emulsions. Food Technol. 18:1796.

Ockerman, H. W. 1971. Quality Control of Post-Mortem Muscle Tissue. The Ohio State University, Columbus.

Pearson, A. M., M. E. Spooner, G. R. Hegerty and L. J. Bratzler. 1965. Emulsifying capacity and stability of soy sodium proteinate, potassium caseinate and non-fat dry milk. Food Technol. 19:1841.

Potter, J. C. 1971. Emulsion Properties and Product Characteristics as Influenced by Unconventional Protein Sources and Fat Types. M.S. Thesis. The Ohio State University.

Swift, C. E., C. Lockett and A. J. Fryer. 1961. Comminuted meat emulsions - The capacity of meats for emulsifying fat. Food Tech. 15:468.

Townsend, W. E., L. P. Witnauer, J. A. Riloff and C. E. Swift. 1968. Comminuted meat emulsions: Differential thermal analysis of fat transitions. Food Technol. 22:319.