EATING QUALITY AND PROTEIN VALUE OF BEEF AND BEEF-COTTONSEED BLENDS

by

BETH ROSE MOLONON

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Approved by:

Jane Bowers

Major Professor

This is dedicated to the man I love and will forever love, whose strength, patience, understanding, and love so inspires my life and work.

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INTRODUCTION

One important unsolved nutritional problem is that of meeting the protein requirements of man. Protein deficiencies arise either from the lack of an adequate food supply, or as a result of social, economical and cultural factors which lower the consumption of vulnerable groups of the population as a whole (WHO/FAO, 1965; Wilcke, 1969). Even in the United States, 2-7% of low income families receive less than two-thirds of the National Research Council's (NRC) recommended dietary allowance for protein (Eagles, 1969).

Presently the protein sources in developed nations are primarily from animal protein (Altschul, 1969). About one-third of food expenditures in the United States is for red meat. The per capita consumption was seventy-eight pounds of beef in 1953 and increased to 109 pounds in 1973 (USDA, 1974). More than 22% of total beef use was ground beef (Wolford, 1974). With increasing population and food cost, it may become necessary to utilize high quality, low cost plant proteins to provide adequate proteins for the population. Such plant protein may be incorporated into the diet by blending with an already familiar and acceptable animal protein source, such as ground beef (Gabby, 1966).

Soy and cottonseed provide high quality proteins and are produced in larger amounts throughout the world than other available plant proteins. However, those plant proteins are of lower quality and are less familiar to the consumer than animal proteins. Hence, the use of soy and cottonseed protein as meat extenders is a practical approach to increase protein consumption without sacrificing nutritional value.

The U.S. Department of Agriculture forecasts use of textured soy proteins by 1980 to be 10-20% of the total beef market, or 2-4 billion pounds of hydrated soy (Bird, 1973; Wilding, 1974). At the present time, the Food and Nutrition Service of the USDA School Lunch Program allows a meat and textured vegetable protein blend (Maximum 30% hydrated vegetable protein, 70% meat) as an acceptable alternative in school lunch programs (FNS, 1971).

FDA approved the use of flour from glanded cottonseed, produced by liquid cyclone process (LCP) as a food additive (U.S. FDA, 1972) but studies on the use of textured cottonseed protein as meat extenders have not been made. The object of this study was to determine eating quality and protein value of beef-cottonseed blends (100, 85, and 70% beef).

REVIEW OF LITERATURE

This review concerns the use of vegetable proteins as meat extenders and their effect on physical and chemical characteristics, eating quality, and nutritive value of the vegetable protein-meat blends. A review of the research on soy as a meat extender is included since little has been reported on other vegetable proteins.

Physical and Chemical Characteristics of Vegetable Proteins

Cooking losses. Soy concentrates absorb about five times and soy isolates about six times their weight of water; they absorb about 1.5 times their weight of oil. Water absorption values of 2.5 times its weight and oil absorption values of 1.5 times its weight have been reported for LCP cottonseed flour (Olson, 1973). Therefore, the addition of such products to meat may reduce cooking losses. Anderson and Lind (1975) formulated 100% beef patties and patties containing 75% beef and 25% hydrated textured soy protein (TSP), hydrated at a ratio of 2 water : 1 soy, and adjusted the mixtures to approximately 15, 20, 25, and 35% fat. The cooked (to 160°F) yields of fried or broiled patties containing soy slightly exceeded those of beef patties. Regardless of the fat and moisture levels of raw patties, beef-soy patties retained more moisture and less fat after cooking than did beef patties.

Yeo et al. (1974) found decreased drip and cooking loss for beef patties with increased concentration of soy curd from full-fat soybeans.

Physical shrinkage, indicated by diameter measurement before and after cooking, was greater for beef patties than for beef-soy patties with 16 and 24% hydrated soy flour and soy protein concentrate (hydrated at a ratio of 3 water : 1 soy) and adjusted to contain 20 and 30% lipid (Judge et al., 1974). The flour reduced shrinkage to a greater extent than did the concentrate. However, Bowers and Engler (1975) reported no difference in diameters of beef and beef-soy (15 and 30% soy hydrated at a ratio of 2 water : 1 soy) patties, cooked to 75°C, but noted cooking losses were decreased by increased addition of hydrated TSP.

Soy products have been added to meat (beef, pork, turkey) used in meat loaf mixtures. There was greater lipid retention in loaves containing 30% soy (hydrated at a ratio of 2 water : 1 soy) cooked to 77°C, than in those containing no soy (Williams and Zabik, 1975). Yoon et al. (1974) cooked meat loaves at 350°F for 45 min and found improved retention of original shape by beef-soy loaves (15 and 30% soy) over beef loaves. Total cooking loss, volatile loss and drip loss decreased with increased percentage of soy protein (hydrated at a ratio of 1.5 water : 1 soy). Nielsen and Carlin (1974) evaluated frozen raw or precooked (to 165°F) beef loaves and precooked beef-soy loaves (30% soy hydrated at a ratio of 1.5 water : 1 soy) and found cooking time was not affected by addition of soy. Soy had no effect on volatile losses of freshly cooked loaves, but reheated beef loaves had 5 times more drip and 3 times more total loss than beef-soy loaves. Beef-soy loaves retained more fat in cooking and reheating, and moisture content of the precooked reheated loaves was lower for the beef-soy loaves than for beef loaves.

Using 8% LCP cottonseed flour in beef patties reduced frying losses and yielded a product with favorable flavor and texture. Cottonseed flour used in meatballs and gravy and in chili decreased separation of fat and increased moisture retention. The flour aided in fat and moisture retention in sausage and can be incorporated into frankfurters at a high level due to limited water absorption (Olson, 1973). Replacement of 25% beef in meat loaves by hydrated cottonseed flour (both glandless and LCP varieties) reduced average cooking losses. The fat phase "cook-out" of beef loaves averaged 2.67 times and the water phase "cook-out" 2.10 times the weight of the beef-cottonseed loaves' "cook-outs" (Lawhon et al., 1972).

Oxidation and bacterial growth. Adding soy to meat may reduce stale or warmed-over flavor (WOF) in cooked reheated meat and increase the product's storage stability since soybeans contain compounds with antioxidant properties. Sangor and Pratt (1974) covered beef slices with solutions of 4 and 10% soy extract and found after 9 days storage at 3°C 2-thiobarbituric acid (TBA) values of beef slices covered with soy were lower than for the slices covered with water. Sato et al. (1973) prepared meat loaves with various non-meat protein products, including 2 and 4% TSP. TBA values and off-flavor scores were lower for beef-soy loaves after 2-5 days storage at 4°C than for the beef loaves or loaves with other vegetable extracts. TBA values of 30% soy substituted turkey loaves were lower after 4 days storage at 5°C than for non-soy loaves (Williams and Zabik, 1975). Bowers and Engler (1975) reported lower TBA values for beef-soy blends (15 and 30% soy) after 8-9 weeks frozen storage (-17°C) than for all beef patties.

Smith (1973) noted that natural tocopherols in cottonseed provide antioxidant activity. Sato et al. (1973) found WOF inhibited by cottonseed flour, possibly due to presence of antioxidant substances produced as a result of interactions between protein and carbohydrates upon heating.

Soy flour and soy protein concentrate had no significant effect on bacterial growth in beef patties after 7 days storage at 4°C (Judge et al., 1974). Schroder and Busta (1971) found soy did not affect growth of C. perfringens in ground beef loaves.

Eating Quality

Taste panels have found the eating quality of ground beef-soy blends acceptable in some studies, but with distinct flavor characteristics. Other eating quality factors appear to be less affected by the addition of soy.

Huffman and Powell (1970) found beef patties (15, 25, or 35% fat) with 2% soy (25 mesh toasted grits) had lower shear press values and were more tender than 100% beef patties. Bowers and Engler (1975) reported that the addition of 15 and 30% TSP increased firmness (texture) of beef patties. Yoon et al. (1974) noted similar texture scores for beef-soy loaves made with 0, 15, and 30% soy. No significant difference in mouthfeel was found between meat loaves (beef, pork, and turkey) containing 0 and 30% soy (Williams and Zabik, 1975).

In one study replacement of 30% ground beef by soy decreased the juiciness of meat loaves (Nielsen and Carlin, 1974). However, Williams and Zabik (1975) found juiciness of pork-soy loaves decreased, but no significant difference was found in meat loaves made from beef or turkey, due to soy substitution. Adding soy to beef patties did not affect juiciness in the study by Bowers and Engler (1975).

Yoon et al. (1974) reported similar color scores for beef loaves with 0, 15, and 30% soy, but scores for appearance (retention of shape) were higher for loaves containing soy.

Uniformity of shape of beef patties was not affected by level of soy (Bowers and Engler, 1975).

Of all the eating quality factors, flavor and aroma are most affected by the addition of soy. However, with frozen storage and reheating the differences in meaty aroma and flavor between beef and beef-soy patties were reduced (Bowers and Engler, 1975). Nielsen and Carlin (1974) found precooking did not alter beef flavor, but soy had the effect of masking beef flavor and contributed a soy flavor to beef-soy loaves. Yoon et al. (1974) reported aroma acceptability decreased with increased level of soy in beef loaves and noted significantly lower flavor acceptability scores for loaves with 30% soy. Flavor intensity scores of turkey and beef loaves decreased slightly with the addition of 30% soy, but were significantly lower only for pork-soy loaves (Williams and Zabik, 1975).

Significantly lower acceptability scores were reported for pork-soy loaves (Williams and Zabik, 1975) and beef-soy loaves (Yoon et al., 1974) at the 30% replacement level. In general, the greater the addition of TSP the less acceptable the freshly cooked patties and meat loaves (Bowers and Engler, 1975; Yoon et al., 1975).

Use of textured cottonseed protein as meat extenders has not been reported, but a few acceptability studies of the use of cottonseed flours in meat have been made.

Consumer panelists in Central America and Panama scored frankfurter-type sausage with 14% cottonseed flour highly acceptable in texture, color, taste, and flavor (FAO, 1961).

Both glandless and LCP cottonseed flour combined with beef produced acceptable meat loaves with a mild, bland taste (Lawhon et al., 1972). Johnson et al. (1975) found cottonseed flour products added to ground beef, pork, and lamb up to a level of 50% by weight did not lessen acceptability appreciably. Ground meat mixtures were used in patties or balls, loaves, stuffed peppers, tacos, sandwich mixtures, and casseroles.

Nutrient Value

If vegetable proteins are to be used as meat extenders, one important concern is the nutritive value of the proteins. Comparison of the essential amino acid pattern with the FAO provisional standard of egg albumin shows soy flour contains an excess of lysine and is well balanced in amino acids other than those containing sulfur, methionine being the limiting amino acid (Kies and Fox, 1971). Debry et al. (1974) obtained similar digestibility, net protein utilization (NPU) and biological values (BV) whether adults were fed TSP or meat protein diets. Mean nitrogen values for adult males fed 8 g nitrogen per day from beef, TVP and 1% DL methionine fortified TVP were similar, but when fed 4 g nitrogen daily from those sources, the values were -.30, -.70, and -.45, respectively. Blood components of those subjects showed no difference in protein compounds, mineral or nitrogenous waste material; iron was absorbed to supply normal hemoglobin levels, calcium bioavailability was unaffected by phytates, purines did not affect uric acid levels (Kies and Fox, 1971). Korslund et al. (1973) conducted similar studies with adolescent boys and found mean nitrogen values comparable to those reported by Kies and Fox (1971). The balance of amino acids in a 70% beef-30% soy blend is comparable to 100% beef. However, measured nitrogen balance of beef and TVP blends (0, 25, 50, 75, and 100% soy) on adult males at nitrogen intake of 4.8 g daily showed the deficit curve increased with increased levels of soy substitution, but was modified by vitamin enrichment (Kies and Fox, 1973).

Puppies (4-6 weeks old) fed soy protein for 16 weeks displayed normal health and growth (Hamdy, 1974). Rats fed soy following a protein-free diet exhibited adequate rate of nutritional recovery (Debry et al., 1974).

Soy protein isolate added at graded levels from 2-25% in a meat blend produced no change in protein efficiency ratio (PER) values of the meat (Mattil, 1974). Rats fed six types of meat protein blends (chicken patties, meat loaves, meatballs, cooked and uncooked patties and chili; tested in combinations of 0, 12, 21 and 30% levels of hydrated soy and containing 17.5% fat) had higher PER values than those fed casein. Chili had a slightly lower PER value possibly due to an increased binding of available lysine from increased browning reaction (Wilding, 1974).

Protein values for textured cottonseed flour have not been reported but work conducted with cottonseed flour showed methionine and leucine were low, with lysine being the limiting amino acid in comparison to the FAO standard reference pattern. However, in growth studies with chicks, Fisher (1965) reported lysine, methionine, leucine, isoleucine and threonine were all limiting amino acids. Yet, cottonseed protein had greater growth promoting ability than soy when lysine was present in broiler rations (Smith, 1969). Cottonseed flour was shown safe for consumption and growth promoting for chickens and rats when lipids were removed and gossypol inactivated (FAO, 1961; Allison, et al., 1962; Bressani, 1965; Braham et al., 1965; Watts, 1965), and effective in treating protein deficiency diseases in young children (Schrimshaw, 1962; Bradfield 1962).

Recently, the protein values of cottonseed flour improved as genetic breeding for glandless cotton and methods of deglanding eliminated the previous deleterious effects produced by reactions to inactivate gossypol, which lowered available lysine and caused it to be reported as the limiting amino acid (Smith et al., 1961; Braham et al., 1965; Bacigalupo, 1966; Vix, 1968; Gastrock et al., 1969; Ziemba, 1972; Ridlehuber and Gardner, 1974). LCP cottonseed flour was reported to contain 70% protein on a moisture free basis and have PER values from 2.51-2.67 (Olson, 1973). There were no substantial differences in the weight gains between rats fed the glandless or LCP cottonseed flours at either 10 or 20% protein level (Harden and Yang, 1975). No study of the protein quality of textured cottonseed protein-meat blends has been reported.

EXPERIMENTAL

Materials

Twenty kilograms of ground beef (approximately 25% fat) were obtained from the meat laboratory of the Animal Science and Industry Department, Kansas State University. Glandless cottonseed flour, 80 mesh (Trader's Mill Corporation, Lubbock, Texas) was tempered overnight by adding 25% moisture in the form of a mist and then textured (C.W. Brabender Extruder, type 2501, no. 527, at 300 psi, 250° F) in the Grain Science and Industry Department, Kansas State University. The textured cottonseed flour (TCF) was hand-ground in a Quaker City Mill, to an average particle size of less than 2380 microns and passed through Tyler screen no. 8 (8 mesh). One gram of TCF was mixed with 5 ml of water for 10 min and then centrifuged to determine water absorption properties of the particles. TCF was hydrated with water and added to the ground beef as follows:

Mixture	Ground beef, g	Water, g	TCF, g
100% beef	7890	---	---
85% beef	6783	798	399
70% beef	5586	1596	798

Blends were mixed with a Hobart mixer (model L-800) for 2 min at no. 1 speed (68 rpm), then percentage moisture was determined by drying 10 g samples at 121°C for 60 min in a C.W. Brabender Semi-Automatic Rapid Moisture Tester, (type SAS, no. 271) and color was measured with a Gardner Automatic Color Difference Meter (model AC-2A, series 200).

Physical and Chemical Measurements and Sensory Evaluation

Sixteen (165 g) portions of each mixture were placed in individual plastic bags and held frozen (-15°C) for 4-7 weeks until analyzed. Two portions of each treatment were defrosted for 48 hours at 4° C and molded into patties (9.5 cm in diameter) at each of seven periods. Patties were placed on wire racks 7 cm high in a shallow pan, in a rotary hearth electric oven at 350°F (177°C) and cooked to an internal temperature of 75°C. Total cooking time and cooking losses were calculated. One pattie was ground and 50 g were frozen immediately for future analysis of protein, fat, and moisture content (AOAC, 1970). Color determination was made with a Gardner Automatic Color Difference Meter on the remaining portions.

A randomized complete block (day) design was used, and data were analyzed by analysis of variance with seven replications for each of the three treatments. When treatment differences were significant ($P<0.05$) LSD's were calculated.

The second pattie was cut diagonally into six wedges and placed in a warm ceramic dish, to present to the six-membered panel for sensory evaluation in individual booths. Intensity of flavor and aroma components were scored (1, absent; to 7, intense). Juiciness (1, dry; to 7, moist), texture (1, soft, mealy; to 7, firm, rubbery), and overall acceptability were also scored.

A latin square design was used for the sensory evaluation and data were analyzed by analysis of variance as follows:

Source of variation	DF
Squares (S)	13
Order/Square	28
Subject/Square	28
Treatment (T)	2
T x S	26
Error	28

When treatment differences were significant ($P<0.05$) LSD's were computed.

Protein Quality Evaluation

Five (1 kg) loaves of each mixture were formed in pyrex loaf dishes and cooked at 350°F in a rotary hearth electric oven to an internal temperature of 75°C. Total cooking time and cooking losses were calculated. Loaves were cooled at 4°C overnight and broken into chunks, then freeze-dried to an average of 4% moisture. Freeze-dried material was ground through a Kenmore meat grinder (3/8 in. plate) and mixed in a Hobart mixer (model A-120) for 3 min at no. 2 speed

(113 rpm). Freeze-dried samples were analyzed for protein, fat, and moisture content (AOAC, 1970). A Beckman Amino Acid Analyzer (model 120 C) was used to determine amino acid content of hydrolyzed (6N HCl, 24 hr) samples.

Forty male weanling rats (21 days of age) of the Sprague-Dawley strain, weighing 45-50 g, were divided into five groups with similar total weights and used to evaluate the protein quality of different diets. The diets formulated according to NRC (1963) specifications, contained 10% fat, 4% minerals, 0.3% vitamins, 1% water, 5% cellulose, and 10% protein (excluding diets 1 and 2) in addition to cornstarch.

Food and water were provided ad libitum for a 28 day experimental period. Weekly and ten day weight gain and food intake were recorded. Net protein ratios (NPR) were calculated after ten days feeding, by the formula: NPR = weight gain of test animal + average weight loss of non-protein group animals/protein intake. PER's as measured and as corrected to a casein PER of 2.5 were calculated after 28 days feeding by the formula: PER = g body gain in weight/g protein ingested. Feces were collected during the third and fourth weeks of the study to determine digestibility coefficients (DC) by the formula: DC = (intake N - fecal N/intake N) x 100.

The diets, 1) casein; 2) non-protein; 3) 100% beef; 4) 85% beef + TCF; and 5) 70% beef + TCF; were assigned to the cages by a randomized complete block (cage level) design. Data were analyzed by analysis of variance with eight animals for each of five diets. When treatment differences were significant ($P<0.05$) LSD's were calculated.

RESULTS AND DISCUSSION

Mean values of seven replications for 3 beef and TCF blends along with significance of F-values and LSD's are presented in Table 1.

Physical and Chemical Characteristics

There were no significant differences in cooking losses (percentage volatile, drip and total loss) between treatments. This is not in agreement with the findings of Lawhon et al. (1972) who reported reduced cooking losses in meat loaves with 25% beef replaced by hydrated cottonseed flour, and this is unlike results reported for soy which decreased cooking losses in beef patties (Anderson and Lind, 1975; Bowers and Engler, 1975). Probably the initial hydration level (2 water : 1 TCF) prevented the systems from binding additional moisture, since in a preliminary investigation the particles demonstrated ability to absorb a maximum of 2 times their weight of water. Cooking time did not vary among blends.

Table 1--Means of physical and chemical measurements of cooked beef-TCF patties

Parameter	100% beef	85% beef	70% beef	Significance of F-value	LSD*
Total cooking loss, %[a]	31.01	32.08	30.12	ns	---
Volatile loss, %[a]	20.34	20.45	20.39	ns	---
Drip loss, %[a]	10.66	11.63	9.86	ns	---
Cooking time, min	43.29	43.29	43.43	ns	---
Moisture, %	57.98	59.68	60.27	ns	---
Protein, %	26.33	27.54	25.92	ns	---
Fat, %	17.38	12.71	12.31	***	1.86
Rd value	20.0	20.5	20.8	*	0.6
a+ value (redness)	5.4	4.7	4.1	***	0.3
b+ value (yellowness)	10.1	10.5	11.0	***	0.3

[a] Based on raw weight

*** $P<0.001$; ** $P<0.01$; * $P<0.05$; [ns] Not significant

The cooked patties had similar moisture and protein content but the 100% beef patties had higher fat content ($P<0.001$). The TCF contained less than 1% fat and calculated values for percentage fat content of the raw blends were approximately 25% for the 100% beef, 21.25% for the 85% beef blend and 17.5% for the 70% beef blend. Therefore, we expected the fat content would decrease with increased levels of TCF in the cooked sample. In beef patties with soy, Anderson and Lind (1975) found increased moisture retention and decreased fat retention, but increased lipid retention in meat loaves with 30% TSP was reported (Nielsen and Carlin, 1974; Williams and Zabik, 1975).

The color of the cooked 100% beef patties was darker ($P<0.05$) than that of the 70% beef blend, as indicated by Gardner Rd values, and redness decreased while yellowness increased with increased levels of TCF ($P<0.001$). However, no visual difference in appearance was noted by the researcher.

Sensory Evaluation

Beef aroma and flavor scores decreased and cereal aroma and flavor scores increased with increased levels of TCF ($P<0.01$), a trend consistent with the findings in studies of soy-meat blends (Nielsen and Carlin, 1974; Bowers and Engler, 1975). The TCF alone had a bland flavor with no distinct characteristics, but with aroma notes of cereal (oatmeal),

Table 2--Means of sensory evaluations[a] of cooked beef-TCF patties

Parameter	100% beef	85% beef	70% beef	Significance of F-value	LSD*
Aroma:					
beef	6.1	4.0	2.7	***	0.4
cereal	1.2	3.6	4.9	***	0.5
Flavor:					
beef	6.1	4.4	3.0	***	0.4
cereal	1.2	3.1	4.7	***	0.5
Texture	4.4	4.3	3.8	*	0.5
Juiciness	5.3	4.6	4.6	**	0.4
Overall acceptability	6.2	5.0	4.0	***	0.3

[a] Intensity scale of 1-7

*** $P<0.001$; ** $P<0.01$; * $P<0.05$; ns Not significant hay, and grain. Meat loaves with cottonseed flour were milder or more bland in flavor than all-beef loaves, and had a softer or smoother texture (Lawhon et al., 1972). Texture was scored similarly for 100 and 85% beef blends but significantly lower (softer, mealier) for the 70% beef blend ($P<0.05$). Juiciness was scored alike for 70 and 85% beef patties but higher for the 100% beef patties ($P<0.001$) probably due to higher fat content of the all-beef patties. Nielsen and Carlin (1974) found soy-substituted meat loaves were less juicy, but Bowers and Engler (1975) reported the addition of soy to beef patties had no effect on juiciness. Overall acceptability scores decreased with increased level of TCF ($P<0.001$) but were above 4.0 on a seven point scale, and acceptable. Similar results have been obtained with soy-meat blends but acceptance scores for cottonseed-beef blends were higher than those reported by Bowers and Engler (1975) for soy-beef blends, in a similar kind of evaluation.

Protein Value

Essential amino acid contents of the three beef blends decreased with increased levels of TCF (Fig. 1), but comparison to the FAO provisional pattern showed all blends to be similar. Harden and Yang (1975) found cottonseed flour was low in isoleucine and methionine.

Biological evaluation by a rat feeding study showed all blends supported growth (as indicated by PER values) similarly and at a higher rate than did the casein control (Table 3). Wilding (1974) found lower PER's with higher

Fig. 1--Essential amino acid contents g/16 g N

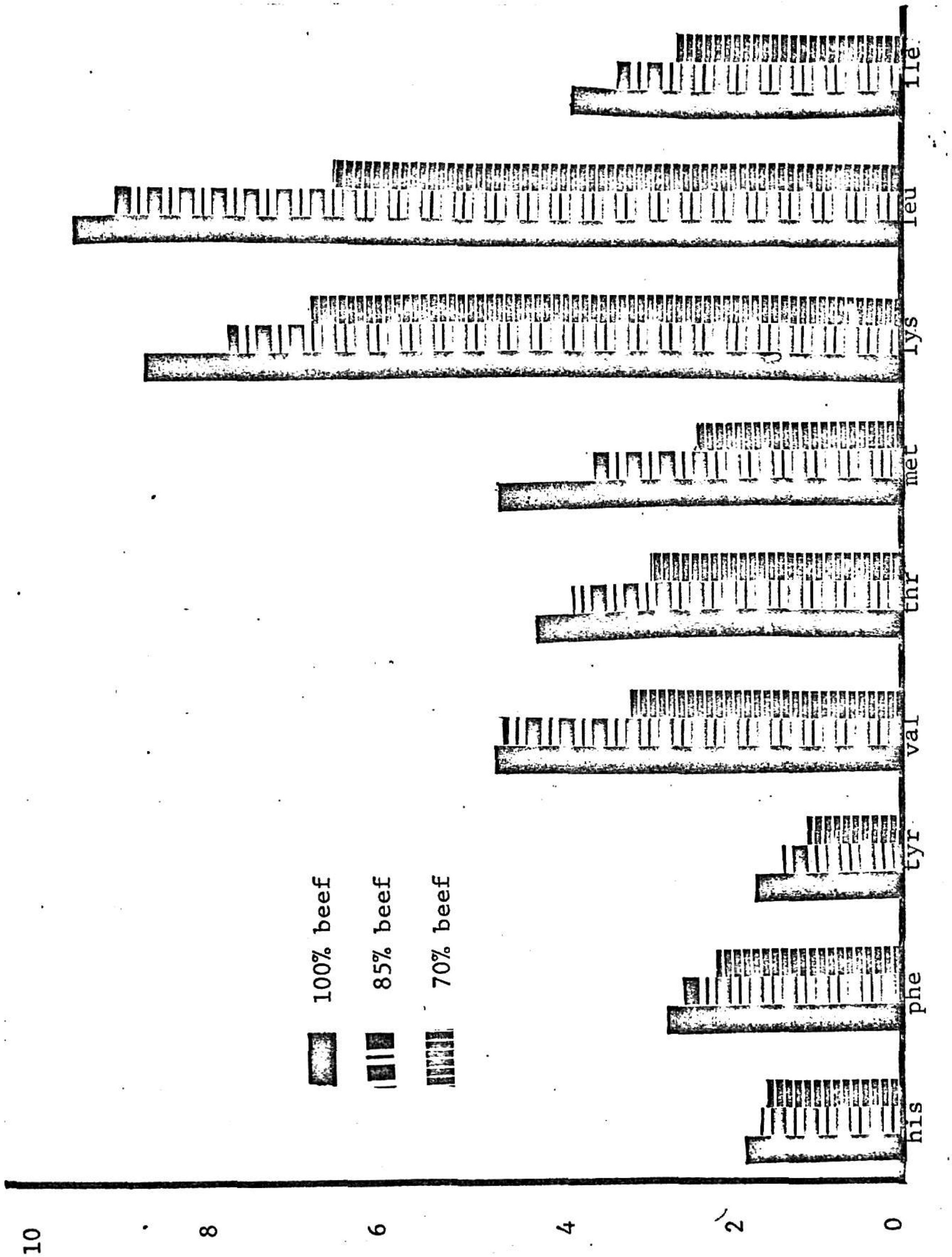
100% beef
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Table 3--Means of biological evaluations of protein quality

Parameter	Casein	100% beef	85% beef	70% beef	Significance of F-value	LSD*
Intake[a], g protein	9.1	10.8	10.7	11.4	***	0.9
Gain[a], g	35	51	51	46	***	6
NPR	5.0	5.6	5.7	4.9	*	0.7
Intake[b], g protein	38.2	49.4	49.9	48.3	**	4.7
Gain[b], g	114	168	174	155	***	19
PER	3.0	3.4	3.5	3.2	**	0.3
PER[c]	2.5	2.8	2.9	2.7	**	0.2
DC	95.85	96.07	95.91	95.27	ns	---

[a] Values after ten days

[b] Values after 28 days

[c] Values adjusted to a 2.5 value for casein

*** $P<0.001$; ** $P<0.01$; * $P<0.05$; ns Not significant levels of soy in blends, and Kies and Fox (1973) reported this trend in nitrogen balance of human subjects fed beef-soy blends. But ten day NPR values (indicating maintenance and growth promoting ability) were similar for 100 and 85% beef blends though significantly lower for the 70% beef blend ($P<0.05$). DC values were not significantly different and were excellent for all treatments.

SUMMARY

Selected physical and chemical measurements, sensory evaluations, and protein value determinations were made on 100% beef, 85% beef + TCF, and 70% beef + TCF blends. A randomized complete block (day) design with seven replications of each treatment was used for physical and chemical measurements; a latin square design with seven replications of each treatment was used for sensory evaluations; and protein quality was evaluated as a randomized complete block (cage level) design with eight animals for each of five diets. Data were analyzed by analysis of variance, and LSD's were calculated.

Cooking losses and cooking time, moisture, and protein content were not affected by treatment. Fat content was higher ($P<0.0001$) for 100% beef patties, and those patties were darker ($P<0.05$) as measured by Gardner Rd values than patties of the 70% blend. Redness decreased while yellowness increased with increased levels of added TCF ($P<0.001$).

Taste panel scores for beef flavor and aroma decreased and cereal flavor and aroma scores increased ($P<0.01$) with increased levels of TCF. Texture was similar for 100 and 85% beef patties and firmer than that for 70% beef blend ($P<0.05$). Beef patties (100%) were juicier ($P<0.01$) than those with TCF. Acceptability decreased with increased level of TCF ($P<0.01$) but all treatments were scored above 4.0 on a seven point scale.

Essential amino acid contents decreased with increased levels of TCF, but feeding studies with weanling rats resulted in higher PER values for test diets than for casein ($P<0.01$). NPR values of 100 and 85% blends were similar and higher than for 70% blend ($P<0.05$). All treatments had excellent digestibility.

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APPENDIX

Table 4--Composition of materials

Material	Ash, %	Protein, %	Moisture, %	Ether extract, %	Crude fiber, %
Cottonseed flour	8.86	57.86	5.61	0.91	0.91
TCF	8.27	55.17	10.91	0.01	0.59
100% beef[a]	---	57.60	3.91	37.21	---
85% beef + TCF[a]	---	58.09	4.72	31.66	---
70% beef + TCF[a]	---	55.89	4.84	29.55	---
Casein	---	91.46	5.95	---	---

[a] Cooked and freeze-dried

Table 5--Select measurements on raw materials

Measurement	100% beef	85% beef	70% beef
Gardner color value[a]			
Rd	14.5	13.6	15.6
a+ (redness)	17.8	17.5	12.4
b+ (yellowness)	9.5	9.4	9.3
Brabender moisture[b]			
Moisture, %	55.0	55.1	55.9

[a] Standardized by tile no. V0030 (Rd 5.5, a+ 26.8, b+ 13.0)

[b] Determined after 60 min at 121°C

Table 6--Amino acid content of beef-TCF blends, g/16 g N

Amino acid	100% beef	85% beef	70% beef
Essential amino acids			
histidine	2.00	1.89	1.88
isoleucine	4.06	3.58	2.81
leucine	9.69	9.23	6.73
lysine	8.82	7.88	6.98
methionine	4.77	3.82	2.67
cysteine	0.76	0.67	0.38
phenylalanine	2.87	2.74	2.43
tyrosine	1.94	1.65	1.34
threonine	4.29	4.08	3.13
valine	4.81	4.72	3.29
Non-essential amino acids			
alanine	10.21	10.05	6.96
arginine	3.73	4.05	4.40
aspartic acid	8.92	7.35	7.26
glutamic acid	18.23	19.11	16.05
glycine	13.87	16.56	9.64
proline	4.06	3.91	3.40
serine	4.90	4.85	3.88

Table 7--Cooking loss and cooking time measurements of cooked beef-TCF patties

Measurement	100% beef	85% beef	70% beef
Total cooking loss, %[a]	28.48	32.21	28.04
	33.33	32.31	32.02
	35.60	32.70	29.80
	30.09	31.02	27.49
	30.82	34.13	30.39
	31.51	32.02	30.69
	27.21	30.18	32.42
Mean	31.00	32.08	30.12
Volatile loss, %[a]	19.69	20.97	18.90
	21.40	21.03	21.14
	20.50	21.20	21.10
	19.14	19.27	17.82
	21.45	22.46	20.97
	21.21	19.93	20.66
	18.96	18.29	22.12
Mean	20.34	20.45	20.39

Table 7--Concluded

Measurement	100% beef	85% beef	70% beef
Drip loss, %[a]	8.78	11.24	9.14
	11.92	11.28	10.87
	15.10	11.50	9.60
	10.94	11.74	9.66
	9.36	11.68	9.42
	10.80	12.08	10.03
	8.25	11.89	10.30
Mean	10.66	11.63	9.86
Cooking time, min	40	46	40
	47	44	47
	43	43	43
	46	43	39
	43	43	43
	44	44	44
	40	40	48
Mean	43.29	43.29	43.43

[a] Based on raw weight

Table 8--Composition of cooked beef-TCF patties

Measurement	100% beef	85% beef	70% beef
Moisture, %	56.28	57.08	59.39
	55.64	58.13	61.53
	57.46	58.99	59.14
	60.11	62.00	63.59
	58.27	63.32	62.00
	61.63	58.80	58.58
	56.47	59.45	57.68
Mean	57.98	59.68	60.27
Protein, %	26.13	27.21	25.33
	28.23	26.13	25.57
	25.78	27.95	26.99
	27.79	27.41	24.72
	26.78	28.82	26.03
	24.07	27.31	26.73
	25.52	27.92	26.08
Mean	26.33	25.54	25.92
Fat, %	15.96	13.30	12.34
	21.60	13.99	11.37
	18.38	13.23	12.82
	16.38	11.24	12.75
	16.56	11.14	11.97
	15.40	15.25	13.00
	17.37	10.85	11.93
Mean	17.38	12.71	12.31

Table 9--Gardner color values of cooked beef-TCF patties

Measurement	100% beef	85% beef	70% beef
Rd value (reflectance)	19.1	19.0	20.0
	19.7	20.7	20.5
	19.9	21.3	20.6
	20.3	19.6	21.3
	20.1	21.0	21.7
	20.1	20.5	20.8
Mean	20.0	20.5	20.8
a+ value (redness)	6.0	4.7	4.3
	5.1	4.3	3.8
	5.6	5.0	4.0
	5.3	4.9	4.3
	5.0	4.1	4.2
	5.6	4.5	4.2
	5.5	5.1	3.6
Mean	5.4	4.7	4.1
b+ (yellowness)	9.8	10.5	11.3
	10.0	10.0	10.7
	10.2	10.8	11.1
	10.2	10.6	11.2
	9.7	10.6	11.0
	10.6	10.3	10.8
	10.1	10.6	10.9
Mean	10.1	10.5	11.0

Table 10--Analysis of variance mean squares for physical and chemical measurements of cooked beef-TCF patties

	Source of variation (df)		
Measurement	Day (6)	Treatment (2)	Error (12)
Total cooking loss	5.68	6.74	3.72
Volatile loss	2.93	0.02	1.18
Drip loss	1.94	5.50	1.96
Cooking time	5.22	0.05	8.10
Moisture	8.42	9.92	2.89
Protein	0.47	4.93	1.43
Fat	2.43	55.54	2.55
Rd value	0.83	1.18	0.25
a+ value	0.15	3.38	1.57
b+ value	0.06	1.57	0.07

Table 11--Latin squares (3 x 3) for sensory evalutaion

	Day 1	2	3	4	5	6	7
	Order 1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3	1 2 3
Member							
1	C B A	A C B	B C A	C A B	A C B	C A B	B A C
2	B A C	C B A	C A B	B C A	B A C	A B C	C B A
3	A C B	B A C	A B C	A B C	C B A	B C A	A C B
4	A C B	C A B	B C A	A B C	B C A	B A C	A C B
5	B A C	A B C	A B C	B C A	A B C	C B A	B A C
6	C B A	B C A	C A B	C A B	C A B	A C B	C B A

A 100% beef

B 85% beef

C 70% beef

Name ______________

Trial ______________

Date ______________

Scorecard for beef patties

Sample	aroma beef	aroma cereal	texture	juiciness	flavor beef	flavor cereal	overall acceptability
1							
2							
3							

aroma, flavor		texture		juiciness		acceptability	
7	intense	7	firm, rubbery	7	moist	7	acceptable
6		6		6		6	
5		5		5		5	
4		4		4		4	
3		3		3		3	
2		2		2		2	
1	absent	1	soft, mealy	1	dry	1	not acceptable

Table 12--Sensory evaluations of cooked beef-TCF patties; range: 1.0-7.0[a]

Measurement	100% beef	85% beef	70% beef
Aroma: beef	6.0	4.8	2.5
	6.2	3.3	2.7
	6.0	3.7	3.3
	6.3	3.8	3.2
	6.2	4.0	2.7
	6.2	3.5	2.2
	5.7	4.5	2.5
Mean	6.1	4.0	2.7
cereal	1.2	2.5	4.5
	1.2	4.5	4.8
	1.0	3.7	4.3
	1.3	3.7	4.8
	1.0	3.7	5.3
	1.2	4.5	5.0
	1.5	2.8	5.3
Mean	1.2	3.6	4.9

Table 12--Continued

Measurement	100% beef	85% beef	70% beef
Flavor: beef	6.0	4.7	3.2
	5.8	3.7	3.3
	6.0	4.3	3.2
	6.2	4.5	3.3
	6.5	4.8	3.3
	6.3	4.2	2.5
	6.0	4.8	2.5
Mean	6.1	4.4	3.0
cereal	1.0	2.5	4.2
	1.3	4.0	4.8
	1.2	3.3	3.8
	1.5	3.0	4.5
	1.2	2.8	4.5
	1.0	3.5	5.3
	1.5	2.8	5.2
Mean	1.2	3.1	4.7

Table 12--Concluded

Measurement	100% beef	85% beef	70% beef
Texture	4.5	4.2	3.5
	4.2	4.0	3.5
	4.2	4.3	3.8
	4.5	3.8	3.8
	4.7	4.8	3.7
	4.3	4.3	4.3
	4.5	4.7	3.8
Mean	4.4	4.6	4.6
Juiciness	5.7	4.7	4.2
	5.8	4.7	4.8
	4.8	5.0	5.2
	4.8	6.7	5.3
	5.3	4.5	4.8
	5.2	4.3	4.0
	5.5	4.3	4.2
Mean	5.3	4.6	4.6
Overall acceptance	5.8	5.0	3.8
	6.3	4.2	4.0
	6.2	5.2	4.2
	6.3	5.5	4.0
	6.5	5.2	4.2
	6.3	5.0	3.7
	5.8	5.3	3.8
Mean	6.2	5.0	4.0

[a] Based on average of six panel member's scores

Table 13--Analysis of variance mean squares for sensory evaluations of cooked beef-TCF patties

Source of variation	DF	Aroma beef	Aroma cereal	Flavor beef	Flavor cereal	Texture	Juiciness	Acceptance
Squares (S)	13	1.32	1.29	0.99	1.11	1.47	1.40	0.83
Order/Square	28	0.79	1.37	1.09	1.91	1.40	0.75	0.50
Member/Square	28	2.31	1.79	2.33	2.75	0.99	1.40	0.98
Treatment (T)	2	121.06	147.77	99.39	125.48	4.67	6.22	52.60
T x S	26	0.95	1.18	0.60	0.92	1.30	0.79	0.59
Error	28	0.72	1.17	0.66	1.29	1.09	0.83	0.45

Table 14--Cooking time and cooking losses of beef-TCF loaves (1 kg)

Measurement	100% beef	85% beef	70% beef
Total cooking loss, %	29.68	27.06	26.96
	32.09	27.40	26.13
	30.62	27.97	28.74
	33.16	27.33	26.59
	31.50	28.81	26.10
Mean	31.41	37.71	26.90
Volatile loss, %	12.47	10.87	11.41
	9.75	10.84	11.44
	9.63	10.76	10.55
	10.85	10.85	11.16
	11.00	11.14	11.40
Mean	10.74	10.89	11.19

Table 14--Concluded

Measurement	100% beef	85% beef	70% beef
Drip loss, %	17.20	15.69	15.55
	22.33	15.86	13.77
	29.98	17.10	16.78
	22.31	15.58	14.31
	20.10	16.97	12.80
Mean	20.58	16.24	14.64
Cooking time, min	75	67	67
	66	67	73
	66	67	73
	75	67	72
	65	67	72
Mean	69	67	71

Table 15--Randomized complete block (cage level) design used for animal growth study

Row	Side A (facing, left-right)					Row	Side B (facing, left-right)				
1	2	4	5	3	1	2	1	5	3	4	2
3	2	3	5	4	1	4	1	3	5	2	4
5	2	4	5	1	3	6	5	4	3	2	1
7	3	1	4	5	2	8	2	3	5	4	1

1 Casein

2 Nonprotein

3 100% beef

4 85% beef + TCF

5 70% beef + TCF

Table 16--Composition of diets (7 kg) used for animal growth study

	Treatment				
Ingredient	Casein	Nonprotein	100% beef	85% beef	70% beef
Protein, g	700[a]	0	1215	1205	1253
Fat,[b] g	700	700	248	319	330
Water, g	70	70	22	13	10
Vitamin mixture,[a,c] g	21	21	21	21	21
Mineral salt-choline,[a,d] g	294	294	294	294	294
Cellulose,[a] g	350	350	350	350	350
Cornstarch,[a] g	4865	5565	4849	4798	4743

[a] Nutritional Biochemicals, Ohio

[b] Beef tallow prepared by Oscar Mayer & Co.

[c] Evaluation of Protein Quality--Pub. 1100, NAS,NRC, 1963; p.31

[d] Mineral salts 282 g, choline 12 g

Table 17--Weekly measurement feed consumption, g and weight gain, g of animals

					First week						
Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain
1-1[a,b]	73	29	3-1	69	29	4-1	77	37	5-1	92	39
1-2	82	30	3-2	87	43	4-2	85	40	5-2	90	37
1-3	77	29	3-3	81	37	4-3	81	38	5-3	86	33
1-4	75	29	3-4	92	43	4-4	70	30	5-4	78	35
1-5	76	24	3-5	77	28	4-5	82	36	5-5	80	32
1-6	67	21	3-6	87	38	4-6	77	38	5-6	85	30
1-7	86	24	3-7	88	40	4-7	89	42	5-7	87	35
1-8	71	23	3-8	87	38	4-8	53	21	5-8	84	35
Mean	76	26		84	37		77	35		74	35

Table 17--Continued

					Second week						
Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain
1-1	81	24	3-1	105	34	4-1	121	46	5-1	140	52
1-2	89	29	3-2	119	56	4-2	129	49	5-2	115	46
1-3	129	33	3-3	143	46	4-3	122	51	5-3	87	21
1-4	91	26	3-4	122	40	4-4	130	51	5-4	113	42
1-5	106	25	3-5	109	45	4-5	105	42	5-5	102	50
1-6	92	17	3-6	121	43	4-6	64	24	5-6	127	51
1-7	111	26	3-7	109	42	4-7	130	49	5-7	144	51
1-8	96	24	3-8	142	44	4-8	106	39	5-8	118	37
Mean	99	2.6		121	44		113	44		118	40

Table 17--Continued

Third week											
Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain
1-1	92	25	3-1	126	41	4-1	155	51	5-1	145	43
1-2	105	18	3-2	148	56	4-2	182	51	5-2	144	44
1-3	127	39	3-3	136	43	4-3	159	55	5-3	98	17
1-4	100	23	3-4	142	26	4-4	160	52	5-4	147	46
1-5	127	34	3-5	134	41	4-5	147	45	5-5	151	44
1-6	108	22	3-6	137	44	4-6	121	37	5-6	87	12
1-7	100	18	3-7	135	44	4-7	159	50	5-7	152	43
1-8	129	35	3-8	152	49	4-8	125	43	5-8	134	41
Mean	111	26		139	43		151	48		132	36

Table 17 --Concluded

					Fourth week						
Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain
1-1	108	37	3-1	136	39	4-1	162	43	5-1	136	30
1-2	123	38	3-2	156	46	4-2	166	48	5-2	141	38
1-3	161	42	3-3	144	41	4-3	164	49	5-3	132	41
1-4	128	29	3-5	126	38	4-4	159	47	5-4	148	45
1-5	140	34	3-5	152	45	4-5	154	47	5-5	183	49
1-6	155	34	3-5	162	45	4-6	161	53	5-6	145	65
1-7	130	37	3-7	155	51	4-7	155	44	5-7	161	41
1-8	144	43	3-8	169	50	4-8	143	41	5-8	136	41
Mean	136	37		150	44		158	47		148	44

[a] Diet treatment: 1, casein 3, 100% beef 4, 85% beef 5, 70% beef

[b] Row of cage (1-8)

Table 18--Feed consumption and weight gain measurements of animals on tenth day of study (measured in g)

Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain	Rat	Intake	Gain
1-1[a,b]	95	39	3-1	91	38	4-1	110	50	5-1	126	55
1-2	96	40	3-2	102	60	4-2	118	55	5-2	107	54
1-3	105	40	3-3	113	53	4-3	113	51	5-3	111	35
1-4	91	39	3-4	105	57	4-4	99	45	5-4	106	49
1-5	106	34	3-5	104	41	4-5	110	49	5-5	111	46
1-6	92	28	3-6	115	51	4-6	109	50	5-6	117	33
1-7	111	32	3-7	115	51	4-7	119	53	5-7	123	49
1-8	96	31	3-8	121	53	4-8	80	53	5-8	114	48
Mean	99	35		108	50		107	48		114	46

Table 18--Concluded

Rat	Intake	Gain
2-1	57	-7
2-2	53	-10
2-3	49	-8
2-4	60	-6
2-5	55	-20
2-6	61	-9
2-7	60	-9
2-8	48	-10
Mean	55	-10

[a] Diet treatment: 1, casein 3, 100% beef 4, 85% beef 5, 70% beef 2, non-protein

[b] Cage level (row)

Table 19--28-day measurements of weight gain, protein intake, PER, and DC[a] of animals

Rat	Weight gain, g	Protein intake, g	PER	DC
1[b]-1[c]	115	32.4	3.5	95.00
1-2	115	36.5	3.2	95.28
1-3	134	42.7	3.1	94.45
1-4	107	34.0	3.1	96.63
1-5	117	42.1	2.8	96.23
1-6	94	39.6	2.4	94.99
1-7	105	39.1	2.7	97.44
1-8	125	39.3	3.2	96.79
Mean	114	38.2	3.0	95.85

Table 19--Continued

Rat	Weight gain, g	Protein intake, g	PER	DC
3-1	143	43.6	3.28	95.81
3-2	201	51.0	3.94	96.36
3-3	167	50.4	3.31	94.90
3-4	147	48.2	3.05	95.20
3-5	159	47.2	3.37	96.09
3-6	170	50.7	3.35	96.91
3-7	177	48.7	3.63	96.15
3-8	181	55.0	3.29	96.72
Mean	168	49.4	3.40	96.07

Table 19--Continued

Rat	Weight gain, g	Protein intake, g	PER	DC
4-1	177	51.5	3.44	95.31
4-2	188	56.2	3.35	96.74
4-3	193	52.6	3.67	96.17
4-4	180	51.9	3.47	94.76
4-5	170	48.8	3.48	95.38
4-6	152	42.3	3.59	96.00
4-7	185	53.3	3.47	97.11
4-8	144	42.7	3.37	95.88
Mean	173	49.9	3.48	95.92

Table 19--Concluded

Rat	Weight gain, g	Protein intake, g	PER	DC[a]
5-1	164	51.3	3.20	95.09
5-2	165	49.0	3.37	95.57
5-3	112	40.3	2.78	95.38
5-4	168	48.6	3.46	94.62
5-5	175	51.6	3.39	96.14
5-6	128	44.2	2.90	95.04
5-7	170	54.4	3.13	94.25
5-8	154	47.2	3.26	96.09
Mean	154	48.3	3.18	95.27

[a] DC = (intake nitrogen -fecal nitrogen/intake nitrogen) x 100; determined on feces collected third and fourth weeks of study

[b] Diet treatment: 1, casein; 3, 100% beef; 4, 85% beef 5, 70% beef; 2, non-protein

[c] Cage level (row)

Table 20--Analysis of variance mean squares for measurements of animal growth

Source of variation	DF	NPR	PER	DC
Block (cage level)	7	0.93	0.05	0.72
Treatment	3	1.34	0.38	0.99
Error	21	0.42	0.07	0.60

EATING QUALITY AND PROTEIN VALUE OF BEEF AND BEEF-COTTONSEED BLENDS

by

BETH ROSE MOLONON

B.S., University of Michigan, 1974

AN ABSTRACT OF A MASTER'S THESIS

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With the increasing use of vegetable proteins to extend meats, the eating quality and protein value of those blends are of interest. Selected physical and chemical measurements, sensory evaluations and protein quality values of 100% beef, 85% beef + textured cottonseed flour (TCF), and 70% beef + TCF were studied.

Though cooking losses and cooking time, moisture, and protein content were unaffected by the use of TCF, fat content of the 100% beef patties was higher, and Gardner color values indicated redness decreased and yellowness increased with increased levels of TCF.

Beef flavor and aroma decreased and cereal flavor and aroma increased with increased levels of TCF. Patties of 100 and 85% beef were similar but firmer than those of 70% beef, and 100% beef patties were juicier. Acceptability decreased with increased levels of TCF, but all treatments were scored above 4.0 on a seven point scale.

Essential amino acid contents decreased with increased level of TCF, but rat feeding study protein efficiency ratios (PER) showed all treatments supported growth at a higher rate than did casein. Net protein ratios (NPR) of 100 and 85% beef blends were similar and higher than for 70% beef blend. All treatments had excellent digestibility.