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Title: AN EVALUATION OF COMPOSITION AND QUALITY OF GROUND BEEF SOLD IN RETAIL STORES

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The composition and some qualitative aspects of ground beef offered for sale in Corvallis, Oregon were studied. Samples were purchased from six retail markets twice weekly throughout a six week test period. Three stores were independently owned and operated and three were chain stores.

Differences in moisture, fat and protein levels of ground beef samples among the six stores and between chain and independently owned stores were statistically significant. Differences in composition between sampling days (Tuesday versus Friday) and between replicate weeks were generally not significant. Ground beef from chain stores was generally characterized by higher moisture and protein levels and lower fat levels. Thirty-two percent of all samples (50 percent of the independent stores and 14 percent of the chain stores) exceeded the legal limit of 30 percent fat.

Moisture:protein ratios ranged from 2.53 to 4.24 while the average value was 3.59. About 28 percent of all samples had ratios in excess of 3.70. Differences in moisture:protein ratios between chain and independent stores were not significant.

Although differences in extract-release volume (ERV) of ground beef obtained from the various stores were significant, differences between sampling days, replicate weeks and chain versus independent stores were not. Resazurin reduction times of ground beef among individual stores, between sampling days, replicate weeks and chain versus independent stores were not significantly different. The correlation between ERV and resazurin reduction time was low ($r = 0.21$) suggesting a poor relationship between these two procedures for assessing microbial contamination in ground beef.

Differences in nonprotein nitrogen (NPN) levels of samples among stores and between sampling days were statistically significant. Only minor differences in NPN levels between store types and replicate weeks were observed. Soluble protein levels appeared to be a reflection of total protein.

Iodine numbers of ground beef fat ranged from 43.7 to 53.6 and were significantly higher in ground beef purchased from chain stores.

Price per pound of ground beef and price per pound of protein were significantly different among the six stores. The price per pound of meat was significantly higher in the chain stores than in the

independent stores. However, price per pound of protein and price per pound of soluble protein were essentially the same for the two types of stores.

Recommendations for quality control of ground beef sold at the retail level are discussed.

AN EVALUATION OF COMPOSITION AND QUALITY OF GROUND BEEF SOLD IN RETAIL STORES

by

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INTRODUCTION

Ground beef accounts for approximately one-third of the fresh meat purchased. Although it is the sales leader among fresh meats, it is probably subject to more abuse and mishandling than any other fresh product sold (Houston, 1963).

The manner in which the raw materials (meat scraps and fat trimmings) are obtained and processed into ground beef allows for the product to become highly contaminated with microorganisms. This contamination also is influenced by the sanitation and refrigeration procedures employed. In addition, there have been incidents where ground beef has been adulterated by the direct addition of water or by a more subtle method of grinding the meat into ice water on the pretext of applying refrigeration (Anonymous, 1960).

Although regulations pertaining to meat sold in Oregon specify that ground beef may not contain additives nor more than 30 percent fat, there are no stipulations concerning bacterial contents (Houston, 1963). The city of Portland, Oregon, however, has adopted standards to prohibit the sale of ground beef having bacterial counts in excess of 10 million per gram (Watts, 1967).

The objectives of this study were to examine the nature and quality of ground beef sold in certain Corvallis stores over a six week period, and to appraise some of the procedures commonly employed for the evaluation of ground beef. Proximate composition and estimation of microbial contamination were the major categories studied.

LITERATURE REVIEW

Ground beef is a very heterogeneous mixture of beef trimmings resulting from the commercial boning of carcass beef at both the wholesale and retail levels. Most trimmings are the by-product derived from the preparation of the more desirable retail cuts of beef from the shank, flank, shirt, round, and loin areas of the carcass. Such trimmings include both lean and fat. Gullets, tongues, and organ meats such as heart, liver, glands, etc., are not normally found in ground beef nor is clod fat or suet. With the trend for less dietary fat, many stores trim fat from the primal cuts of fresh beef more closely than ever before. Hence, accumulation of trimmable fat represents an economic liability that many retailers tend to alleviate by adding it to ground beef.

Proximate Composition of Ground Beef

Fat, protein, and moisture are the major categories concerned with the proximate composition of meat. Mineral and carbohydrate contents of meat are generally found at levels of 1 percent or less. Variations in these two components have no effect upon the relationship between levels of fat, protein and moisture (American Meat Institute Foundation, 1960).

A wide range of values for fat, protein, and moisture has been reported in studies on the proximate composition of ground beef. Fat contents ranged from 6 to 49 percent in a major survey conducted by Consumers Union (Anonymous, 1960) while Law et al. (1965) reported a narrower range of 14.5 to 35.5 percent. Nevertheless, both studies showed that the fat contents of ground beef may vary considerably.

The range of values for protein was not as variable as those found for fat. A mean value of about 19 percent appears common for most ground beef although protein levels have been reported to range from 14 to 21 percent (Anonymous, 1960). Moisture contents ranged from 36 to 72 percent. As long as the protein level remains relatively constant, meat containing a high percentage of fat will have a correspondingly low level of moisture. Conversely, leaner samples will have fairly high moisture contents (American Meat Institute Foundation, 1960).

The diversity of values reported for the proximate composition of ground beef is the result of individual processing and retailing practices involved per store. In addition, economics are intimately involved since the complete use of meat scraps and fat trimmings might well be the difference between profit and loss.

Palatability of Ground Beef as Influenced by Composition

Palatability and acceptability of ground beef vary with differences in composition. The basic criterion by which most consumers judge quality of ground beef is the degree of leanness (Law et al., 1965; Levie, 1963). When given a choice, most consumers tend to purchase that which appears to have the least fat. Although such meat seems to have the "right appearance," it does not necessarily possess the highest eating quality (Levie, 1963). In a survey of 150 families, Glover (1964) found that ground beef containing 20 percent fat was preferred over 16, 25 and 30 percent levels when served as patties. Conversely, taste panel data collected by Cole, Ramsey, and Odom (1960) indicate that for broiling, ground beef must be at least one-third fat to achieve the most desirable degree of tenderness and juiciness.

Tenderization of ground beef is achieved by grinding whereas juiciness is closely related to the level of fat. Patties made from ground beef having a low fat content (less than 20 percent) were less juicy and had a drier texture than those containing more than 20 percent fat (Anonymous, 1960).

Consumer preference for ground beef is often influenced by method of cookery to be used. Lean ground beef may be more desirable for preparing dishes in which the fat becomes a part of the final product, i.e., meat sauces, meat balls, and meat loaf. Ground beef with high fat content is more suitable for making patties and broiling where considerable fat may be drained off (Cole et al., 1960).

Consumer income also influences acceptability of lean to fat contents of ground beef. High income groups tend to be more critical of high fat levels than low income consumers. The latter group is more accustomed to using ground beef with higher fat contents because such meat is generally less expensive than the leaner mixtures (Anonymous, 1960).

Microbial Aspects of Ground Beef

Spoilage of meats generally indicates that the growth of microbes has caused deleterious changes in appearance, odor and flavor. Although ground meats rarely make the consumer ill, it would be desirable from both aesthetic and health considerations to limit the sale and consumption of a product approaching putrefaction.

Ground beef is an excellent medium for microorganisms, and must be produced and stored with respect to its perishability. When meat is ground, tissues are broken and the liberated cellular fluids mix with bacteria normally found on the meat surface. The macerated tissues provide a very favorable environment for the growth and multiplication of microorganisms. Thus freshness of ground beef is soon lost during storage at temperatures common to retail markets (Rogers and McCleskey, 1961).

Since ground beef makes use of trimmings and scraps which probably have been handled extensively, the total bacterial count per gram of meat is likely to be comparatively high. Rogers and

McCleskey (1957) found total bacterial counts ranging from 1.5 to 230 million per gram for ground beef in various retail markets. Kirsch *et al.*, (1952) reported that aerobic plate counts from 20 different market samples of ground beef ranged from 1.4 to 95 million per gram. Spoilage, as evidenced by odor, was first noted at eight days when the count had reached 500 million or more per gram. They also found that the organisms in ground beef at the time of purchase were a mixture of gram-negative, nonspore-forming rods plus various species of the *Micrococcaceae* family, and occasionally lactobacilli. The ones that grew most rapidly during storage at 0° to 2° C were motile, nonpigmented members of the genus *Pseudomonas* and *Achromobacter*.

Since spoilage is a consequence of microbial activity, bacterial counts have long been suggested as a criterion of quality (Elford, 1936; LeFevre, 1917; Weinzirl and Newton, 1914). Standard plating techniques, however, require 24 to 48 hours before results are available. This delay and the unreliability of total counts as reported by Saffle *et al.* (1961) tend to lessen their value in quality control. Hence, such standards have not been widely accepted. Other workers have considered kinds as well as numbers of bacteria in ground beef at time of purchase or at time of spoilage and have concluded that such tests were also impractical (Brewer, 1925; Foltz, 1941; Hoffstadt, 1924; Weaver, 1927).

Tests based on various biochemical changes resulting from microbial activity, such as the production of ammonia, hydrogen sulfide, indole, ninhydrin-positive substances and picric acid turbidity, have proved to be of little value either because of complexity or poor reproducibility of results, or both (Farber, 1952; Kirsch et al., 1952; Bowlby et al., 1953; Saffle et al., 1961).

Dye reduction tests have been studied rather extensively in recent years to determine whether such tests would distinguish between satisfactory and unsatisfactory food products in reference to bacterial content. The dairy industry has used both methylene-blue and resazurin tests for many years to evaluate the acceptability of cream and milk (Walker et al., 1959). Rogers and McCleskey (1961) found a good relationship between methylene-blue reduction time and bacterial numbers of ground beef stored at 7°C up to 12 days. Novak et al. (1956) reported that methylene-blue reduction was a satisfactory test for approximating bacterial contents of shrimp and oysters.

Straka and Stokes (1957) used resazurin reduction tests to estimate bacterial content of precooked frozen meat pies. They were able to classify the meat pies into three categories based on correlations of bacterial numbers to reduction times. Moreover, they indicated that the degree of predictability of these three categories from reduction tests ranged from 90 to 95 percent. Resazurin reduction tests also have been reported to be fairly successful for estimating microbial quality of processed poultry (Walker et al., 1959; Wells, 1959). Saffle et al. (1961) reported correlation coefficients of 0.92 and -0.80 between resazurin reduction and odor score and total bacterial counts respectively. They concluded from their studies that resazurin reduction was a good predictor of meat quality.

Extract release volume (ERV) has been reported by Jay (1964 a,b) to be a rapid and reliable test for determining microbial quality or "spoilage level" of ground beef. When meat was homogenized with an excess of water, the rate of release of filterable fluid from the slurry in a given time period was associated with extent of spoilage. Relatively large volumes of extract were released from homogenates of fresh ground beef whereas those from spoiled beef released progressively less or none. The ERV decreases almost in a straight-line function as meat undergoes spoilage. Furthermore, the decrease in ERV was found to be associated with an increase in bacterial counts.

Although the ERV phenomenon has not been elucidated, Jay (1964 a,b) has theorized that the increase in water retention was due to changes in protein structure accompanying microbial spoilage. The major limitation of the ERV test is concerned with fat levels. Levels less than 21 percent fat have little influence on ERV values whereas those in excess of 21 percent tend to elevate the values and may give misleading results.

EXPERIMENTAL PROCEDURE

Sample Description

Samples of 1 to 1.5 pounds of prepackaged ground beef were purchased twice weekly from self-service meat displays of five retail food markets in Corvallis. A sixth sample was purchased from bulk display at a local market featuring counter service. Three of the six stores were operated by three of the major food retailing chains in Oregon while the remainder were locally owned independent markets. Samples were obtained on Tuesday and Friday mornings of a six week test period covering late summer and early fall of 1966. These two days were chosen in order to make comparisons between ground beef sold during the early part of the week versus that available at the end of the week when special food sales were in effect. Specific weeks involved were the first two weeks of August, the last three weeks of September, and the first week of October. A total of 72 samples, 12 per store, were analyzed.

After purchase, each sample was thoroughly mixed, divided into two portions, and coded for proper identification. One portion, consisting of approximately 300 gm. was placed in a plastic freezer bag (Kordite polyethylene) and held at 4° C until used later in the day for proximate analysis and microbial evaluation. Remainder of the sample was placed in a Kordite bag excluding as much air as possible, sealed, frozen at -7° C and thus held for determination of both total and soluble protein. Prior to protein analysis, the frozen ground beef was sliced by a mechanical meat slicer to give slices 0.5mm or less in thickness. Approximately 60 gm were thus obtained per sample which was allowed to thaw overnight at 4° C in moisture impermeable containers. Each sample was well mixed before portions were removed for determination of protein.

Proximate Analysis

Moisture

Total moisture was determined by drying, in duplicate, 5 gm samples of ground beef in tared aluminum pans *in vacuo* in 70° C for 24 hours. Weight loss was considered to be the loss of moisture.

Fat

The modified Babcock method (Kelley *et al.*, 1954) was used to measure total fat of samples in triplicate. Nine gm of ground beef were placed in Paley bottles to which 5 ml of water (70° C) were added and the contents thoroughly mixed. Five ml of glacial acetic acid and 15 ml of concentrated sulfuric acid were then added and the mixture agitated. After digestion, centrifugation and further addition of water (70° C), the percentage of fat was measured directly from the graduated stems of the Paley bottles.

Total Protein

The biuret method, as developed by Torten and Whitaker (1964) specifically for measuring protein contents of comminuted meats, was used to estimate total protein. One gm of meat was heated in 20 ml of 0.5 M NaOH in a 50 ml Erlenmeyer flask for 10 minutes and then cooled in an ice-water bath. Contents of the flask were quantitatively transferred to a 50 ml volumetric flask and made to volume with distilled water. The solution was filtered through Whatman No. 3 filter paper to remove elastin particles. Fifteen ml of filtrate were placed in a polyethylene centrifuge tube and 15 ml of anhydrous ether were then added. The tube was capped, and the contents were shaken cautiously, but well, before centrifugation at 8150 x G. Sampling was done from the lower, aqueous layer. Four ml of biuret reagent were added to 1 ml of sample, mixed and the absorbance of the mixture was read exactly 30 minutes later at 540 mμ in a Beckman Model B spectrophotometer. A blank containing 1 ml of water in place of sample was prepared in the same manner. Crystalline bovine albumin was used to prepare a standard curve.

Soluble Protein

Soluble protein was extracted from ground beef by the procedure of Helander (1957) using solvent-to-meat ratios of 10:1 (v/w). Three gm of minced sample were placed in a 40-ml conical, thick-walled centrifuge tube and 30 ml of 1.1 M KI buffered to pH 7.4 with 0.1 M potassium phosphate (0.09 M K_2HPO_4 and 0.01 M KH_2PO_4) were added. The sample was mixed thoroughly on a Vortex rotary mixer before being placed on a mechanical shaker. Sample was agitated continuously for 3 hours at 4° C and then centrifuged for 20 minutes at 1400 x G. The supernatant was filtered through a milk filter disk (Flocron) to remove particles of connective tissue. Filtrate was collected in a 125 ml flask and stored at 4° C. Thirty ml of KI were added to the residual, agitated for another 3 hours, centrifuged, filtered, and the filtrate added to that collected previously. Thirty ml of KI were again added to the residual tissue for a final extraction of 2 hours duration followed by centrifugation, filtration and collection of filtrate as above described. A total of 87 to 88 ml of soluble protein extract was obtained per 3 gm of sample.

The biuret method, described previously for determination of total protein, was used to estimate the soluble protein content of the extract except for the following changes. Ten ml of extract were used in place of 1 gm of meat and the heating of the sample, following the addition of 0.5 M NaOH, was omitted. Otherwise, the procedure was exactly the same as that developed by Torten and Whitaker (1964).

Nonprotein Nitrogen

Five ml of soluble protein extract were mixed with 5 ml of 20 percent TCA (trichloroacetic acid) to precipitate the proteins. After precipitation, the mixture was centrifuged for 20 minutes at 1600 x G and the supernatant filtered through Whatman No. 42 filter paper. Nonprotein nitrogen was determined on the filtrate by the standard A. O. A. C. micro-Kjeldahl procedure (Horwitz, 1960) using the mercuric oxide catalyst and boric acid collection method.

Iodine Number

For determination of Iodine numbers, fat was first removed from the ground beef by solvent extraction according to the procedure of Bhalerao et al. (1961). Skelly Solve F (petroleum ether) was redistilled and the fraction volatilizing between 35° and 55° C was used as solvent. Twelve and one-half gm of ground beef, 25 gm of Na_2SO_4 and 90 ml of solvent were homogenized in a Waring blendor for one minute. The solution was filtered through Whatman No. 1 filter paper while the meat fragments and the Na_2SO_4 were retained in the blendor. Ninety ml of solvent were added to the blendor and the contents were homogenized again for one minute and then filtered. The latter step was repeated a second time and approximately 260 ml of filtrate were collected per sample. The filtrate was evaporated in a rotary film vacuum evaporator until about 10 ml of solution remained. The latter portion was transferred to a 50 ml flask and evaporated to dryness in vacuo at 70° C. The dried samples were stored in a desiccator until analyzed.

The standard A. O. A. C. Hanus method was employed to determine the Iodine numbers of the fat extracted from the various samples of ground beef (Horwitz, 1960).

Microbial Evaluation

The extract release volume and resazurin reduction time were the two methods chosen to assess microbial contamination of the ground beef used in this study.

Extract Release Volume

Sixty gm of each ground beef sample were wrapped and folded tightly in aluminum foil and held at 30° C for one hour. From this point on, all work was carried out in a constant temperature room maintained at 30° C. After temperature equilibration, two 25-gm portions from each sample were homogenized with 100 ml of distilled water (30° C) for two minutes in Waring blendors. Homogenates were poured directly into 4-inch fluted funnels equipped with a sheet of Whatman No. 1 filter paper (18.5 cm) folded thrice so as to make eight sections. Homogenates were not permitted to seep between the folds. The extract was collected in 100-ml graduated cylinders by allowing the fluid to course down the inside. Collection was timed for 15 minutes from the point of pouring the homogenate into the funnel. The 15 minute volumes were measured, averaged and recorded as ERV (extract release volume) as described by Jay (1964a, b).

Resazurin Reduction Time

The resazurin reduction test of Saffle et al. (1961) was modified slightly to eliminate some of the difficulties encountered by excessive fat contents of several samples. Ten ml of Bacto nutrient broth (Difco) plus 0.5 percent yeast extract were placed in a culture tube to which 1 ± 0.01 gm of ground beef was added. The tube was placed on a Vortex mixer and shaken for two minutes. The mixture was then filtered through a double layer of cheese cloth into a 50 ml screwcap culture tube. One ml of resazurin dye solution (prepared by dissolving a standard resazurin tablet in 200 ml of hot distilled water) was added and the tube capped tightly. After the tubes were inverted gently three times to mix dye with sample, they were incubated at 30° C in a covered water bath. Observations were made at 15 minute intervals, and the times when color changed to pink and to colorless were recorded. All tubes, pipettes and media required for this test were sterilized prior to use.

Statistical Analysis

The advice and assistance of the Department of Statistics, Oregon State University, were utilized both for experimental design and guidance in evaluating the data. The results were analyzed by analysis of variance for each quality characteristic of ground beef to determine constancy of product among stores, between days and replicate weeks. In addition, effect of store-day interaction and comparison of chain versus independent stores were studied. Correlation coefficients also were calculated between several quality characteristics of major interest.

RESULTS AND DISCUSSION

The results of this study are discussed on the basis of the following four categories; proximate composition, microbial evaluation, qualitative comparisons, and pricing considerations. However, overlapping of discussion from one category to another may occur since variability in one factor or area is generally reflected in another.

Proximate Composition

Results of the total moisture, fat and protein determinations of the fresh ground beef samples are summarized in Tables 1, 2 and 3, respectively. Data concerning individual values by store and by week are presented in Appendices I, II and III.

Moisture contents of the 72 samples ranged from 48.31 to 66.18 percent. The average moisture content for all samples was 55.34 percent. These values are in agreement with those published by others for ground beef. Data presented by Toepfer et al. (1955) indicate that moisture contents of ground beef obtained from eight beef carcasses averaged 55.7 percent although the range was from 44.6 to 62.5 percent. In cooking studies on ground beef, Nielsen et al. (1967) reported that the raw product had an average moisture value of 59.4 percent. Moisture contents ranging from 36 to 72 percent and from 41 to 73 percent, with an average value of 61 percent for both were reported for "ground meat" and hamburger, respectively, in a survey conducted by Consumers Union (Anonymous, 1960).

Table 1. Mean moisture percentages of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
	I	II	III	IV	V	VI	Mean
Day							
Tues.	56.50	55.04	59.04	55.36	52.13	53.19	55.21
Fri.	59.70	55.99	56.88	56.27	50.89	53.10	55.46
Mean	58.10	55.52	57.96	55.82	51.51	53.10	55.34

Chain stores mean = 57.19 Independent stores mean = 53.48

Variance of means = 0.7716
Variance of means among stores = 0.3858
Variance of means between days = 0.1286

Results of statistical analyses shown in Table 4 failed to reveal significant differences in moisture contents between sampling days, Tuesday versus Friday, or with replicating weeks. However, differences in moisture levels of ground beef among the six stores and between chain (57.19 percent) and independently owned (53.48 percent) stores were significant at the 1 percent level of probability.

Table 2. Mean fat percentages of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
Day	I	II	III	IV	V	VI	Mean
Tues.	25.21	28.29	23.54	28.21	32.65	29.82	27.95
Fri.	23.21	28.79	25.63	27.54	32.75	31.22	28.19
Mean	24.21	28.54	24.58	27.88	32.70	30.52	28.07

Chain stores mean = 25.78 Independent stores mean = 30.37

Variance of means = 2.1507
Variance of means among stores = 1.0753
Variance of means between days = 0.3584

Table 3. Mean protein percentages of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
Day	I	II	III	IV	V	VI	Mean
Tues.	16.38	14.79	16.53	15.35	13.20	15.51	15.29
Fri.	17.40	14.59	16.36	15.64	15.29	16.07	15.89
Mean	16.89	14.69	16.45	15.50	14.25	15.79	15.59

Chain stores mean = 16.01 Independent stores mean = 15.18

Variance of means = 0.3715
Variance of means among stores = 0.1857
Variance of means between days = 0.0619

Fat contents of the 72 samples ranged from 13.50 to 38.50 percent with the average being 28.07 percent. Thirty-two percent of all samples analyzed exceeded the legal limit of 30 percent fat, a standard established by the Oregon Department of Agriculture concerning the sale of ground beef (Houston, 1967). Fifteen of the 24 samples obtained from two of the independent markets (Stores V and VI) had fat contents in excess of the 30 percent limit. Moreover, the data indicate that only five of the 36 samples purchased at chain stores exceeded the legal fat limit whereas 18 of 36, or 50 percent, of the ground beef samples obtained from the independent stores contained more than 30 percent fat.

As observed in comparison of moisture contents of the samples, there were no significant differences in fat levels between sampling days or weeks although differences in fat levels between stores were significant ($P < 0.01$). Fat contents of ground beef obtained from the independent stores (30.37 percent) were found to be significantly higher ($P < 0.01$) than those of samples purchased from the chain stores (25.78 percent).

Significant and non-significant differences in protein levels between stores, days and independent versus chain stores as shown in Table 4 were in accord with the preceding observations made for moisture and fat contents. As suggested by the higher moisture and lower fat levels, the average protein content of chain store ground beef (16.01 percent) was significantly higher ($P < 0.05$) than that of the independent stores (15.18 percent).

Table 4. Mean squares from analysis of variance of proximate composition of fresh ground beef from six stores.

	Moisture	Protein	Fat	Moisture: protein ratio	Fat: protein ratio
Week	7.24	3.75	19.41	0.15	0.16
Store	82.53**	12.20**	131.45**	0.34**	1.28**
Chain vs. Independent	248.51**	12.41*	378.77**	0.0028	2.80**
Day	1.09	6.43	1.02	0.15	0.05
Store x Day	77.39**	0.41	6.42	0.12	0.09

* Differences significant ($P < 0.05$)
** Differences significant ($P < 0.01$)

Protein contents, as determined by the biuret method, ranged from 12.11 to 19.23 percent with the average being 15.59 percent. These values are slightly lower than those recorded by Toepfer et al. (1955), who reported a protein range of 15.30 to 17.70 percent and an average value of 16.10 percent. Data published by Consumers Union (Anonymous, 1960) show a protein range of 14 to 22 percent with a mean value of 19 percent while Nielsen et al. (1967) reported an average protein content of 18.6 percent. In the latter three reports, the Kjeldahl method was used for the determination of protein. This method is considered to account for total nitrogen whereas according to Haurowitz (1963), the biuret reagent reacts with only those molecules containing at least two peptide linkages (polypeptides and proteins). Hence, nonprotein nitrogen is not accounted for by the biuret procedure. When the protein values in this study were re-calculated to include nonprotein nitrogen, the protein range of 12.11 to 19.23 percent was raised to that of 13.44 to 20.81 percent. Also, the average protein content for all samples increased from 15.59 to 17.08 percent.

The biuret procedure as employed in this study does not account for all of the connective tissue that might be present in ground beef. Elastin is not completely solubilized by the NaOH-heat treatment applied for ten minutes during the early stages of the biuret procedure. This treatment facilitates the digestion and solubilization of the proteins (Torten and Whitaker, 1964). Although longer digestion times would allow for more complete solubilization of elastin, such time increases would pose another problem by permitting excessive hydrolysis of the other proteins. The latter condition would result in elevated nonprotein nitrogen levels which would not be detected by the biuret method and thus would also lead to lower protein values.

Torten and Whitaker (1964) compared the biuret method with the standard Kjeldahl procedure for determining protein content of several ground beef samples containing various levels of fat. They reported a highly significant positive correlation ($r = 0.99$) between the two methods. A correlation coefficient of 0.95 was calculated from data of similar studies conducted within our laboratories prior to this study (Putnam, 1965).

The preceding general observations of significant differences concerning the moisture, fat and protein contents of ground beef from six stores in Corvallis, Oregon, supports the assumption that considerable variation exists in the gross composition of the product available to local consumers. Adequate levels of each major component contribute to the maximum nutritional and palatability aspects of ground beef. Disproportionate amounts upset this balance and detract from the over-all desirability of the product (Anonymous, 1960).

Because of merchandizing practices of retailers and the nature of the product, it was speculated that the materials used to make ground beef might be different prior to the weekend, Friday, and subsequent to the weekend, Tuesday. Comparisons of Tuesday and Friday moisture, fat and protein data do not indicate a significant advantage for either day but suggest a rather consistent product throughout the week.

In contrast, comparison of chain and independent store averages indicate significant differences in percentages of moisture, fat and protein attributable to type of store in which the meat was purchased. Ground beef obtained from the chain stores was generally characterized by higher moisture contents (57.19 versus 53.48 percent) and protein levels (16.01 versus 15.18 percent), and lower fat percentages (25.78 versus 30.37 percent).

With the exception of moisture comparisons, examination of the ground beef data generally failed to demonstrate significant interactions between stores and days. The absence of interactions suggests that these factors are, for the most part, independent of one another and that simple effects of one are essentially the same for all levels of the other.

As animal tissues vary in their moisture, fat and protein contents, they also show variation in the relative amounts of these components. Consequently, the moisture:protein and fat:protein ratios will be indicative of these variations. Hence, these ratios might serve as a relative guide for predicting the composition or detecting possible adulteration of meat products. Since considerable variation may exist between samples of similar kinds of meat, caution must be exercised in the interpretation of such results. Approximate moisture:protein ratios of various beef tissues vary from 3.5 for beef trimmings to 3.7 and 3.8 for beef flanks and plates respectively. Organ meats often have higher ratios; for example, beef heart has a moisture:protein ratio of 4.9 (American Meat Institute Foundation, 1960).

Values concerning individual moisture:protein and fat:protein ratios are given in Appendices IV and V and are summarized in Tables 5 and 6, respectively.

Table 5. Mean ratios of moisture:protein of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
	I	II	III	IV	V	VI	Mean
Day							
Tues.	3.46	3.72	3.58	3.66	3.96	3.43	3.64
Fri.	3.44	3.88	3.49	3.63	3.50	3.31	3.54
Mean	3.45	3.80	3.54	3.65	3.73	3.37	3.59

Chain stores mean = 3.60 Independent stores mean = 3.58

Variance of means = 0.0119
Variance of means among stores = 0.0059
Variance of means between days = 0.0020

Table 6. Mean ratios of fat:protein of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
	I	II	III	IV	V	VI	Mean
Day							
Tues.	1.55	1.92	1.45	1.89	2.48	1.92	1.87
Fri.	1.35	2.03	1.57	1.80	2.19	1.96	1.82
Mean	1.45	1.98	1.51	1.85	2.34	1.94	1.85

Chain stores mean = 1.65 Independent stores mean = 2.04

Variance of means = 0.0199
Variance of means among stores = 0.0100
Variance of means between days = 0.0033

Moisture:protein ratios varied from 2.53 to 4.24. The average value of 3.59 is in close agreement with data presented by the

American Meat Institute Foundation (1960) for beef trimmings commonly utilized in ground beef. However, some values, as evidenced by the range, deviate considerably from the average. Approximately 28 percent of all samples had moisture:protein ratios in excess of 3.70, a legal limit set forth by North Dakota Food Laws which state "A normal ratio of moisture/protein should not be greater than 3.5. A ratio of 3.7 or more definitely indicates added water" (Koehler, 1967). Of particular interest is the fact that two stores, one chain (Store II) and one independent (Store V), each exceeded the moisture: protein ratio of 3.7 in seven of the 12 samples analyzed.

Ratios lower than the expected values described above are also of interest. While they could be the result of reduced moisture contents and/or increased protein levels, neither case suggests improved palatability characteristics. Low moisture:protein ratios might also be the result of using partially dried meat trimmings or the addition of some filler-type material.

Results of analysis of variance of moisture:protein ratios listed in Table 4 show significant differences ($P < 0.01$) in ratios between stores but do not indicate any advantage for either chain or independent stores. Failure to detect significant differences between days and between replicate weeks suggest rather surprising uniformity of product with time so far as moisture:protein ratios are concerned.

Data in Table 6 summarizes the individual fat:protein ratios presented in Appendix V. The average fat:protein ratio of 1.85 observed herein is somewhat higher than that of 1.45 calculated from the data of Toepfer et al. (1955) and much larger than the value of 1.00 derived from the data reported by Consumers Union (Anonymous, 1960). Although the range of 0.70 to 2.78 observed in Appendix V compares favorably with that of 0.50 to 2.33 reported by Consumers Union, it shows considerably more latitude than the range of 1.45 to 1.53 obtained from the data of Toepfer et al. (1955).

As shown in Table 4, differences in the fat:protein ratios between stores and between chain and independent stores were significant ($P < 0.01$). On the average, ground beef from independent stores had higher fat:protein ratios (2.04) than that of the chain stores (1.65). In view of the data concerning proximate composition in which ground beef samples from the independent stores were significantly higher in fat and significantly lower in protein contents than the ground beef of the chain stores, these results are not unexpected.

Microbial Evaluation

Since ground beef is generally made from beef trimmings that receive more handling and processing than other fresh meats, it has ample opportunity to become contaminated to various degrees with microorganisms. Both extract release volume (ERV) and resazurin reduction time tests were employed to evaluate the ground beef samples microbially and to determine whether either procedure would be of any value in detecting the level of microbial contamination from a practical standpoint.

Mean values of the ERV tests are presented in Table 7 while the individual results are given in Appendix VI. ERV values for all samples averaged 57.1 ml and ranged from 41.5 to 73.8 ml. None of the values approached 30 ml, a level considered by Jay (1966a, b) to be an early indication of organoleptic spoilage. Jay concluded also that meat having ERV values of 25 ml or below contained an approximate bacterial number per gm of about log 8.5. Statistical analyses (Table 9) indicate that differences in the ERV of ground beef obtained from the various stores were significant at the 1 percent level of probability. However, differences between sampling days, replicate weeks and chain versus independent stores were not significant.

Data concerning the resazurin reduction times are summarized in Table 8 while the detailed results are given in Appendix VII. The average reduction time for all samples was 5.04 hours and the times ranged from 0.25 to 10.09 hours. Straka and Stokes (1957) reported that meat samples having less than 100,000 bacteria per gm required more than five hours to reduce the resazurin dye to colorless. Saffle et al. (1961) obtained a correlation coefficient of -0.80 between total bacterial counts and resazurin reduction to colorless. The latter authors also stated that ground beef which reduced resazurin to colorless in five hours or less had bacterial numbers exceeding log 8.0 per gram.

Table 7. Mean ERV values of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
Day	I	II	III	IV	V	VI	Mean
Tues.	53.58	60.85	54.72	57.52	57.43	61.47	57.60
Fri.	56.85	58.38	55.23	55.97	49.58	63.62	56.61
Mean	55.22	59.62	54.98	56.75	53.51	62.55	57.11

Chain stores mean = 56.61 Independent stores mean = 57.60

Variance of means = 6.7161
Variance of means among stores = 3.3581
Variance of means between days = 1.1193

Table 8. Mean reduction times of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
Day	I	II	III	IV	V	VI	Mean
Tues.	4.74	4.46	5.84	5.33	4.17	5.89	5.07
Fri.	5.39	5.50	5.49	5.66	3.53	4.40	5.00
Mean	5.07	4.98	5.67	5.50	3.85	5.15	5.04

Chain stores mean = 5.24 Independent stores mean = 4.83

Variance of means = 0.7082
Variance of means among stores = 0.3541
Variance of means between days = 0.1180

Although the average reduction time reported herein (5.04 hours) tends to suggest a relatively low level of microbial contamination, the wide range in reduction times (0.25 to 10.09 hours) indicates that considerable variation existed between the samples tested.

Results of statistical analyses of resazurin reduction times are shown in Table 9. These data failed to indicate significant differences between individual stores, between sampling days or replicate weeks or between chain and independent stores.

A positive correlation (r = 0.21) was calculated between the ERV values and resazurin reduction times. The low correlation of seemingly similar tests might be explained, at least in part, by the findings of Rogers and McCleskey (1961). They reported on studies using the methylene-blue reduction test and concluded that reduction test results cannot always be expected to agree with total bacterial counts, ammonia contents or any of the other test measuring microbial products. Since reduction time is dependent on the intensity of the reducing activity of the microflora, it is possible that a population of highly active cells could induce a shorter reduction time than a larger population of less active cells.

Jay (1964a, 1966a) found that when fat contents of meat samples exceeded 21 percent, ERV values increased about 15 percent over analogous samples having less than 21 percent fat. Jay further stated that it was doubtful whether higher levels of fat would alter

Table 9. Mean squares from analysis of variance of microbial evaluation and qualitative data.

	ERV	Reduction Time	ERV/Protein	Reduction Time/Protein	Nonprotein Nitrogen	Soluble Protein	Soluble Protein/Protein	Iodine Number
Week	49.13	5.67	7.74	0.046*	0.160	7.12**	187.47**	24.33**
Store	136.89**	4.86	1.31**	0.020	0.200*	7.00**	215.99	28.50**
Chain vs. Independent	17.80	3.42	1.28	0.004	0.006	13.17**	32.87	42.84**
Day	17.60	0.20	0.82	0.006	0.930**	0.53	18.15	8.30
Store x Day	47.88	2.35	0.51	0.016	0.090	0.25	29.28	2.46

* Differences significant ($P < 0.05$)
** Differences significant ($P < 0.01$)

ERV much beyond that mentioned above since fat releases all of its water within 15 minutes, the time required for completion of the ERV test. In the present study only five of the 72 samples had fat contents below 21 percent.

Since ERV and the water-holding capacity (WHC) were found to be highly related (r = 0.74), Jay (1966a, b) contends that the most likely controlling sites of the ERV and WHC phenomena are the meat proteins which are assumed to be altered as fresh meat spoils from bacterial growth. In this regard, partial breakdown of the proteins would allow for an increase in the water-binding sites. As the percent fat increases, the percent protein generally decreases and the progressively smaller amounts of protein present in high fat content meat provide fewer water-binding sites. Hence, such samples would have elevated ERV values.

Because the major portion of microbial activity of ground beef is assumed to be associated with the lean portion, and the magnitude of ERV is influenced by fat content, ERV values and resazurin reduction times were also evaluated on a fat-free basis. Expression of the ERV values on this basis failed to alter the statistical interpretation of previous results (Table 9). Although there were still significant differences between individual stores ($P < 0.01$), all other comparisons were not measurably different.

Similarly, expression of resazurin reduction times on a fat-free basis generally did not change previously observed resazurin reduction results (Table 9). In contrast to observations made on the basis of whole tissue, there were significant differences ($P < 0.05$) in reduction times per unit of protein between replicate weeks. These results might be of special interest in view of the fact that differences in fat contents of the samples between replicate weeks were not significant. Hence, the validity of expressing reduction times on a fat-free basis as a possible quality index of meat products with high fat contents would seem to merit further investigation.

Presenting ERV values and reduction times on a fat-free basis did not improve the relationship between these factors since a correlation coefficient of -0.11 was calculated as compared to that of 0.21 obtained for corresponding results for the whole tissue.

Degradation of meat proteins by both bacteria and proteolytic enzymes has been long thought to cause nonprotein nitrogen compounds to accumulate with time. Polypeptides, peptides and free amino acids generally form the bulk of such compounds in fresh meats. Thus the determination of relative amounts of nonprotein nitrogenous materials was carried out to learn whether such analysis might provide some measure of the extent of deteriorative changes occurring in ground beef.

The nonprotein nitrogen contents of the ground beef samples are condensed in Table 10 and tabulated individually in Appendix VIII.

These results are presented on the basis of percent protein. Although such data are not usually expressed in this manner, it was a convenient way to incorporate these values in total protein evaluations as well as for other comparisons. Results of analysis of variance (Table 9) indicated that differences in nonprotein nitrogen levels among stores and between sampling days were significant at the 5 and 1 percent levels of probability respectively. Average nonprotein nitrogen content of all samples was 1.49 percent protein while the levels ranged from 0.74 to 2.36 percent protein. Mean nonprotein nitrogen value for the independent stores was 1.48 percent protein as compared to 1.50 percent protein for the chain stores. Average level for the Tuesday samplings was 1.60 percent protein which was significantly higher ($P < 0.01$) than that of 1.37 percent obtained for the Friday samplings. Differences in nonprotein nitrogen levels apparently were not a function of the differences observed in total protein levels since expression of the nonprotein contents on the basis of protein:nonprotein nitrogen ratios revealed similar results, namely significantly higher Tuesday levels.

In a review of the post-mortem influences on the microbiology of meats, Jay (1966b) has concluded that the evidence to date indicates that beef which is allowed to spoil at refrigerated temperatures does not undergo proteolysis to the extent of accumulation of significant levels of nonprotein nitrogen. Moreover, he contends that spoilage flora subsist on low molecular weight compounds found in the sarcoplasm and upon autolyzed bacterial cells.

Table 10. Mean nonprotein nitrogen percentages[1] of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
	I	II	III	IV	V	VI	Mean
Day							
Tues.	1.62	1.46	1.70	1.52	1.60	1.70	1.60
Fri.	1.51	1.24	1.43	1.40	1.05	1.60	1.37
Mean	1.57	1.35	1.57	1.46	1.33	1.65	1.49

Chain stores mean = 1.50 Independent stores mean = 1.48

Variance of means = 0.0130
Variance of means among stores = 0.0065
Variance of means between days = 0.0021

[1]Expressed as percent protein.

Qualitative Comparisons

Data concerning proximate composition provide information only about the gross aspects of ground beef. In an attempt to provide additional information on some of the more qualitative characteristics of ground beef, supplementary tests were employed.

Soluble protein was extracted from the various samples by the procedure of Helander (1957) involving the use of 1.1 M KI solution and prolonged agitation. Since connective tissue proteins (collagen and elastin) are relatively insoluble in KI, they remain in the residue upon centrifugation while the soluble proteins reside in the supernatant. The biuret procedure was then used to determine the protein content of the supernatant. Nutritionally, the soluble proteins possess a better balance and array of the essential amino acids than the connective tissue proteins. In addition, increases in the amount of connective tissue in ground meats generally results in a reduction in the texture and juiciness characteristics of such meats (American Meat Institute Foundation, 1960). Hence, the connective tissue content of ground beef should be minimized in order to keep the organoleptic quality high.

Results of the soluble protein determinations are summarized in Table 11. Individual values are shown in Appendix IX. The mean soluble protein content for all samples was 10.26 percent while the individual values ranged from 6.75 to 13.96 percent. These data generally reflect the same differences that were observed in the evaluation of total protein contents.

Results of statistical analyses (Table 9) show significant differences among the levels of soluble protein of ground beef obtained from the six stores ($P < 0.01$). While differences in soluble protein between sampling weeks were significant ($P < 0.01$), differences between sampling days (Tuesday versus Friday) were not. Larger total protein contents noted in ground beef obtained from the chain stores were also reflected in the soluble protein levels. The mean soluble protein level of 10.69 percent for ground beef from the chain stores was significantly higher ($P < 0.01$) than the average of 9.84 percent for that obtained from the independent markets.

Table 11. Mean soluble protein percentages of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
	I	II	III	IV	V	VI	Mean
Day							
Tues.	11.05	9.75	11.24	10.20	9.16	9.63	10.17
Fri.	11.38	9.78	10.90	10.58	9.45	10.02	10.35
Mean	11.22	9.77	11.07	10.39	9.31	9.83	10.26

Chain stores mean = 10.69 Independent stores mean = 9.84

Variance of means = 0.1935
Variance of means among stores = 0.0967
Variance of means between days = 0.0363

Soluble protein results were somewhat altered when considered on the basis of soluble protein:protein ratios. From this standpoint, differences (Table 9) between stores and sampling days were not significant which tends to suggest that variations in soluble protein contents are, at least in part, a function of the proximate composition.

Some interesting results can be obtained when the soluble protein is considered as a percentage of the total protein. Such calculations indicate that for all samples the soluble protein ranged from 47.2 to 79.9 percent of the total protein and had an average value of 66.0. Chain stores had a slightly higher average value than the independent stores, 66.6 versus 65.3 percent. Unpublished data obtained in this laboratory on the organoleptic evaluation of ground beef indicated that when soluble protein, expressed as a percentage of total protein, fell below a level of 60 percent, palatability characteristics such as texture, tenderness and juiciness were adversely affected (Putnam, 1965).

Oxidative deterioration of meat associated with the onset and development of rancidity leads to undesirable flavor and odor changes. The greater the degree of unsaturation the more susceptible the fat is to the development of rancidity. The extent of unsaturation of the ground beef was determined by the Iodine number. Values reported herein are expressed as the number of centigrams of iodine absorbed per gm of fat according to the conditions of the test (Horwitz, 1960). Fat with a higher Iodine number deteriorates or becomes rancid sooner than that with a lower Iodine number. Moreover, values beyond the expected range reported for beef fat could lead one to suspect the addition or adulteration of ground beef with unsaturated fats of non-bovine origin.

Data in Table 12 and Appendix X show that the Iodine numbers ranged from 43.7 to 53.6 and had an average value of 48.7. These values agree with data published by others (Mehleubacher, 1960; American Meat Institute Foundation, 1960) which show Iodine numbers to range from 40 to 48.

Table 12. Mean Iodine numbers of ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
	I	II	III	IV	V	VI	Mean
Day							
Tues.	50.18	50.02	48.29	48.00	45.25	48.70	48.41
Fri.	50.40	49.74	48.47	50.16	46.60	49.13	49.08
Mean	50.29	49.88	48.38	49.08	45.93	48.92	48.75

Chain stores mean = 49.52   Independent stores mean = 47.97

Variance of means = 0.4456
Variance of means among stores = 0.2228
Variance of means between days = 0.0743

Statistical evaluation of the above data (Table 9) indicate that differences in Iodine numbers among stores were significant ($P < 0.01$). This finding might be a reflection of the nature of materials used by the individual stores in producing their product. Non-significant differences in Iodine numbers between sampling days, along with significant differences ($P < 0.01$) between replicate weeks might be due to the wholesale meats available to the merchants rather than to their merchandizing practices. While the quality of the carcass meat available might be quite uniform within a week, considerable variation might be found over an extended span of time. On the other hand, a single purchase of meat by some retailers might provide for the entire week's requirements whereas large volume stores may utilize two or three shipments per week.

Differences in Iodine numbers of the ground beef obtained from the two types of stores were significant ($P < 0.01$). Iodine numbers of ground beef of the chain stores averaged 49.5 as compared to a value of 48.0 for that of the independent stores.

Pricing Considerations

Data pertaining to the cost per pound of ground beef are summarized in Table 13 while the individual results are presented in Appendix XI. The average price per pound of meat was 49 cents while individual prices ranged from 39 to 55 cents per pound.

Results of analysis of variance (Table 14) of these data show that differences in price per pound of ground beef among stores ($P < 0.01$) and between replicate weeks ($P < 0.05$) were significant although differences between sampling days were not. In addition, a store-day interaction was also apparent.

On the average, the price per pound of ground beef was significantly higher ($P < 0.01$) in the chain stores (51 cents) than in the independent stores (48 cents). In viewing these data, however, it was of interest to note that one of the independent stores (Store V) had the lowest average price (41 cents/pound) while another independent market (Store VI) had the highest (53 cents/pound). Moreover, chain store prices were more stable. They ranged from 49 to 55 cents per pound whereas the independent stores ranged from 39 to 55 cents per pound.

Table 13. Mean prices per pound of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
	I	II	III	IV	V	VI	Mean
Day							
Tues.	0.49	0.49	0.53	0.49	0.41	0.52	0.49
Fri.	0.50	0.49	0.50	0.49	0.41	0.53	0.49
Mean	0.50	0.49	0.52	0.49	0.41	0.53	0.49

Chain stores mean = 51 Independent stores mean = 48

Variance of means = 0.0002
Variance of means among stores = 0.0001
Variance of means between days = non-significant

Since protein is the most important nutritional component of meat, comparison of ground beef price data on a protein basis would be a more objective means of evaluating meat quality than price per pound of meat <u>per se</u>. Such comparisons are summarized in Table 15 while individual values are listed in Appendix XII. These data show that the prices ranged from $2.04 to $4.05 per pound of protein with the average price being $3.16.

Table 14. Mean squares from analysis of variance of price data of fresh ground beef from six stores.

	Price per pound of ground beef	Price per pound of protein	Price per pound of soluble protein
Week	0.0027	0.4610**	6.1010**
Store	0.0199**	0.4680**	1.7348**
Chain vs. Independent	0.0136**	0.0022	0.1750
Day	0.0001	0.2500	0.2343
Store x Day	0.0027*	0.0760	0.1211

* Differences significant ($P < 0.05$)
** Differences significant ($P < 0.01$)

Table 15. Mean prices per pound of protein of ground beef obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
	I	II	III	IV	V	VI	Mean
Day							
Tues.	3.01	3.33	3.25	3.25	3.09	3.38	3.22
Fri.	2.91	3.41	3.09	3.18	2.70	3.32	3.10
Mean	2.96	3.37	3.17	3.22	2.90	3.35	3.16

Chain stores mean = 3.17 Independent stores mean = 3.16

Variance of means = 0.0170
Variance of means among stores = 0.0085
Variance of means between days = 0.0028

Statistical analyses (Table 14) of the above data show that differences in price per pound of protein among stores and between replicate weeks were significant ($P < 0.01$) whereas differences between sampling days were not. The mean price per pound of protein was practically the same for both types of stores. Chain stores had an average price of $3.17 per pound of protein as compared to $3.16 for the independent stores.

It was also of interest to compare price data on the basis of soluble protein content. Results concerning the average cost per pound of soluble protein are given in Table 16 while individual data are presented in Appendix XIII. Price per pound of soluble protein ranged from $3.51 to $6.55 with the average being $4.82. Statistical results of these data follow those obtained for the price per pound of protein. Table 14 indicates that differences in price per pound of soluble protein between stores and replicate weeks were significant ($P < 0.01$) while those between sampling days were not. Although the mean price per pound of soluble protein of ground beef from independent stores ($4.86) was slightly higher than that for the chain stores ($4.77), the difference was not statistically significant. This implies that it was the manner of merchandizing utilized by the individual store that was important so far as protein values were concerned. Such values were not dependent upon type of store (chain versus independent).

Table 16. Mean prices per pound of soluble protein of ground beef obtained from six Corvallis stores.

	Store Designation						
	Chain			Independent			
	I	II	III	IV	V	VI	Mean
Day							
Tues.	4.45	5.08	4.77	4.85	4.50	5.47	4.85
Fri.	4.50	5.18	4.64	4.72	4.34	5.33	4.79
Mean	4.48	5.13	4.71	4.79	4.42	5.40	4.82

Chain stores mean = 4.77 Independent stores mean = 4.86

Variance of means = 0.0548
Variance of means among stores = 0.0274
Variance of means between days = 0.0091

SUMMARY AND CONCLUSIONS

An investigation of the composition and quality of ground beef offered for sale in Corvallis, Oregon, was completed by examining a total of 72 samples purchased from six retail stores, twice weekly during a test period of six weeks. Three of the stores were independently owned and operated while the other three were chain stores. Data concerned with proximate composition were obtained by the determination of moisture, fat and protein levels of each sample. Resazurin reduction time and extract release volume (ERV) were the procedures utilized for microbial evaluation. In addition, soluble protein and nonprotein nitrogen contents and Iodine numbers were determined. Some effects of price were also considered from a general standpoint. Appropriate statistical procedures were used to analyze the results directly and to make comparisons of other data of pertinent interest.

Moisture contents of the 72 samples ranged from 48.31 to 66.18 percent while the average for all samples was 55.34 percent. Differences in moisture levels among the six stores and between chain (57.19 percent) and independently owned (53.48 percent) stores were statistically significant ($P < 0.01$). Differences in moisture contents between sampling days (Tuesday versus Friday) and between replicate weeks were not significant.

Fat contents ranged from 13.5 to 38.5 percent with the average being 28.07 percent. Fat levels of ground beef purchased from the independent stores (30.37 percent) were significantly higher ($P < 0.01$) than those of samples obtained from chain stores (25.78 percent). Thirty-two percent of all samples analyzed exceeded the legal limit of 30 percent fat. Fifty percent of the samples from the independent stores had fat contents in excess of 30 percent as compared to only 14 percent of the samples from the chain stores.

Protein contents ranged from 12.11 to 19.23 percent with the average being 15.59 percent. Inclusion of the average nonprotein nitrogen expressed as percent protein would raise the mean protein value from 15.59 to 17.08 percent. Average protein content of chain store ground beef (16.01 percent) was significantly higher ($P < 0.01$) than that of the independent stores (15.18 percent).

Moisture:protein ratios ranged from 2.53 to 4.24 while the average value was 3.59. About 28 percent of all samples had ratios in excess of 3.70. Ratios exceeding the latter value might be indicative of adulteration of ground beef by the addition of either water or organ meats. Differences in moisture:protein ratios between chain and independent stores were not significant.

ERV values ranged from 41.5 to 73.8 ml with the average being 57.1 ml. None of the values approached a level of 30 ml which is considered to be a value indicative of early organoleptic spoilage.

Although differences in ERV of ground beef obtained from the various stores were significant ($P < 0.01$), differences between sampling days, replicate weeks and chain versus independent stores were not.

Resazurin reduction times varied from 0.25 to 10.09 hours with the mean being 5.04 hours. Differences in reduction times among individual stores, between sampling days, replicate weeks and chain versus independent stores were not significant. Correlation between ERV and resazurin reduction results was low ($r = 0.21$) indicating a poor relationship between these two procedures for assessing microbial contamination.

Nonprotein nitrogen contents expressed as percent protein ranged from 0.74 to 2.36 percent protein. Only minor differences in nonprotein nitrogen levels between independent and chain stores were observed. Average level for the Tuesday samplings was 1.60 percent protein which was significantly higher ($P < 0.01$) than that of 1.37 percent obtained for the Friday samplings.

The mean soluble protein content for all samples was 10.26 percent while individual values ranged from 6.75 to 13.96 percent. The average soluble protein content of 10.69 percent for ground beef of the chain stores was significantly larger ($P < 0.01$) than the average of 9.84 percent for that obtained from the independent stores. Levels of soluble protein appeared to be a reflection of the total protein contents.

Iodine numbers ranged from 43.7 to 53.6 and had an average value of 48.7. Iodine numbers of ground beef of the chain stores averaged 49.5 which was significantly higher ($P < 0.01$) than the mean value of 48.0 for the meat of the independent stores.

The average price per pound of ground beef was 49 cents while individual prices varied from 39 to 55 cents per pound. On the average, the price per pound of meat was significantly higher ($P < 0.01$) in the chain (51 cents) than in the independent stores (48 cents). In considering costs on the basis of protein content, the prices ranged from $2.04 to $4.05 per pound of protein with an average price of $3.16. Chain stores had an average price of $3.17 per pound of protein as compared to $3.16 for the independent stores. Price per pound of soluble protein ranged from $3.51 to $6.55 with the average being $4.82. Price per pound of soluble protein of ground beef from independent stores ($4.86) was slightly higher than that for the chain stores ($4.77) although the difference was not statistically significant.

In conclusion, the following recommendations might provide some impetus for better control of the quality of ground beef sold at the retail level:

1. Since ground beef sold in Oregon may not contain more than 30 percent fat, this limitation should be followed more rigorously. Approximately one-third of all samples analyzed had fat contents in excess of 30 percent which appears to be more than a

coincidence.

2. Water:protein or fat:protein ratios might be used advantageously to stabilize the quality of ground beef. Water:protein ratios should not be greater than 3.8 or possibly 3.9 while the fat:protein ratio should not exceed a value of 1.5. The use of semi-automatic moisture and fat determination instruments might be readily adapted for such needs at the retail level.

The problem of estimating microbial contamination remains to be solved. A relatively quick, simple and inexpensive procedure to assay bacterial loads is needed. Resazurin reduction time test as employed in this study does not meet the above requirements. Evaluation of microbial contamination by the ERV procedure appears to offer some hope for use at the retail level. However, difficulties and interpretation of data from samples containing fat levels in excess of 21 percent must be resolved before such procedure can be utilized.

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APPENDICES

Appendix I. Individual moisture percentages of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	52. 31	57. 23	55. 87	55. 51	52. 91	48. 85
	58. 16	59. 20	60. 74	56. 38	51. 02	51. 30
Tues.	56. 73	53. 34	56. 59	53. 05	55. 44	56. 86
	56. 75	52. 89	57. 71	51. 39	50. 70	53. 20
	57. 40	54. 87	66. 18	55. 81	52. 71	54. 63
	57. 66	52. 73	57. 13	60. 04	50. 01	54. 30
$\overline{X}$ [1]	56. 50	55. 04	59. 04	55. 36	52. 13	53. 19
	63. 75	52. 96	55. 23	58. 54	49. 89	51. 51
	54. 37	58. 69	55. 46	54. 50	48. 31	52. 54
Fri.	59. 13	61. 29	57. 00	52. 65	52. 24	54. 00
	62. 73	56. 20	57. 55	58. 64	52. 85	55. 34
	59. 89	55. 17	56. 16	57. 95	52. 53	53. 03
	58. 33	51. 62	56. 90	55. 33	49. 53	51. 65
$\overline{X}$	59. 70	55. 99	56. 88	56. 27	50. 89	53. 01

[1] $\overline{X}$ = Mean of 6 samples

Appendix II. Individual fat percentages of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	27.75	25.75	25.50	26.50	30.00	33.50
	20.50	21.50	20.75	27.75	31.75	29.25
Tues.	20.75	30.00	32.00	31.25	33.85	33.14
	27.75	29.25	24.00	32.00	33.30	27.25
	23.75	29.75	13.50	27.75	33.00	26.75
	25.75	33.50	25.50	24.00	34.00	29.00
$\overline{X}$ [1]	25.21	28.29	23.54	28.21	32.65	29.82
	15.75	30.75	26.00	27.00	22.25	33.50
	27.75	25.50	25.00	26.50	38.50	31.50
	27.00	23.50	26.00	32.00	34.50	33.80
Fri.	20.75	32.00	25.50	25.00	30.00	27.80
	23.75	31.00	24.25	28.75	35.75	28.25
	24.25	30.00	27.00	26.00	35.50	32.50
$\overline{X}$	23.21	28.79	25.63	27.54	32.75	31.23

[1] $\overline{X}$ = Mean of 6 samples

Appendix III. Individual protein percentages of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	19.14	14.59	14.89	15.39	17.14	14.98
	17.03	16.77	17.29	16.10	19.10	17.15
	17.52	17.41	16.81	12.41	14.21	15.14
Tues.	17.59	12.69	16.05	17.79	14.36	16.65
	16.13	13.29	17.74	17.38	12.86	17.39
	16.96	12.79	15.37	14.78	14.04	15.12
$\overline{X}$[1]	16.38	14.79	16.53	15.35	13.20	15.51
	14.24	14.78	15.26	13.55	12.85	14.83
	16.58	15.39	16.61	16.93	12.99	15.37
	16.50	15.41	16.53	15.03	14.92	16.19
Fri.	17.04	14.76	16.01	12.11	12.27	15.24
	16.79	14.19	19.23	17.73	13.46	16.18
	17.14	14.20	15.52	16.73	12.73	15.25
$\overline{X}$	17.40	14.60	16.36	15.64	15.29	16.07

[1] $\overline{X}$ = Mean of 6 samples

Appendix IV. Individual ratios of moisture:protein of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	3.67	3.87	3.66	4.10	4.12	3.29
	3.51	3.85	3.66	3.33	3.93	3.34
Tues.	3.44	3.46	3.42	3.53	3.72	3.51
	3.33	3.58	3.60	4.24	4.13	3.49
	3.42	3.87	3.44	3.15	3.92	3.38
	3.36	3.71	3.68	3.59	3.93	3.56
$\overline{X}$ [1]	3.46	3.72	3.58	3.66	3.96	3.43
	3.33	3.64	3.71	3.80	3.49	3.44
	3.19	3.50	3.21	3.39	2.53	3.06
Fri.	3.38	3.52	3.39	4.24	3.68	3.57
	3.57	4.43	3.59	3.30	3.68	3.32
	3.71	4.15	3.33	3.33	4.08	3.05
	3.44	4.04	3.70	3.74	3.53	3.42
$\overline{X}$	3.44	3.88	3.49	3.63	3.50	3.31

[1] $\overline{X}$ = Mean of 6 samples

Appendix V. Individual ratios of fat:protein of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	1.95	1.74	1.67	1.96	2.33	2.26
	1.24	1.40	1.25	1.64	2.44	1.90
Tues.	1.56	1.95	1.94	2.08	2.27	2.05
	1.63	1.98	1.50	2.65	2.71	1.79
	1.41	2.10	0.70	1.57	2.45	1.66
	1.50	2.36	1.64	1.44	2.67	1.90
$\overline{X}$[1]	1.55	1.92	1.45	1.89	2.48	1.92
	0.82	2.11	1.74	1.75	1.30	2.24
	1.63	1.52	1.45	1.65	2.02	1.84
	1.54	1.35	1.55	2.58	2.43	2.23
Fri.	1.18	2.52	1.59	1.41	2.09	1.67
	1.47	2.33	1.37	1.65	2.78	1.62
	1.43	2.35	1.76	1.76	2.53	2.15
$\overline{X}$	1.35	2.03	1.57	1.80	2.19	1.96

[1] $\overline{X}$ = Mean of 6 samples

Appendix VI. Individual ERV values of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	62.5	52.5	55.5	58.0	56.3	60.5
	52.0	60.0	52.0	50.0	54.5	41.5
Tues.	48.0	62.5	57.0	58.5	52.0	68.5
	49.5	65.8	61.0	64.3	56.5	73.0
	53.5	62.3	49.3	56.3	70.0	64.3
	56.0	62.0	53.5	58.0	55.3	61.0
$\overline{X}$ [1]	53.6	60.9	54.7	57.5	57.4	61.5
	54.0	56.5	52.5	60.0	43.5	62.5
	55.8	61.5	56.0	58.5	41.5	54.8
Fri.	71.5	53.5	54.3	57.5	52.5	61.8
	44.5	57.0	53.0	47.5	59.0	67.0
	52.0	54.8	60.3	58.3	42.5	73.8
	63.3	67.0	55.3	54.0	58.5	61.8
$\overline{X}$	56.9	58.4	55.2	56.0	49.6	63.6

[1] $\overline{X}$ = Mean of 6 samples

Appendix VII. Individual reduction time of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	7.58	4.42	4.50	4.50	7.58	4.58
	1.50	1.33	2.17	3.33	0.25	5.15
Tues.	5.33	6.42	4.92	6.09	6.75	4.09
	5.75	4.09	10.09	5.33	6.17	7.50
	4.17	4.09	9.17	5.58	1.83	5.50
	4.09	7.50	4.17	7.17	2.42	8.50
$\overline{X}$[1]	4.74	4.46	5.84	5.33	4.17	5.89
	6.17	4.58	4.58	6.34	5.42	4.92
	6.25	4.83	7.42	6.92	5.67	2.92
Fri.	7.58	2.92	2.25	4.50	2.17	3.25
	3.33	8.83	8.09	3.33	3.00	5.33
	4.42	4.50	3.17	6.67	2.00	6.83
	4.58	7.33	7.42	6.17	2.92	3.17
$\overline{X}$	5.39	5.50	5.49	5.66	3.53	4.40

[1] $\overline{X}$ = Mean of 6 samples

Appendix VIII. Individual non-protein nitrogen percentages (on protein base) of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	1.51	1.80	1.91	1.51	1.84	2.36
	1.76	2.13	2.06	1.76	1.69	1.40
Tues.	1.54	1.40	1.76	1.33	1.69	1.47
	1.21	1.06	1.39	1.40	1.76	1.76
	1.99	1.40	1.40	1.54	1.33	1.55
	1.73	0.99	1.66	1.58	1.29	1.66
$\overline{X}$ [1]	1.62	1.46	1.70	1.52	1.60	1.70
	1.69	0.96	1.25	0.78	0.59	1.33
	1.54	1.25	1.54	1.18	0.74	1.40
Fri.	1.47	1.54	1.47	1.33	1.54	1.73
	1.84	1.03	1.40	2.06	1.33	1.63
	1.17	1.11	1.54	1.58	1.03	1.76
	1.36	1.58	1.40	1.47	1.07	1.76
$\overline{X}$	1.51	1.24	1.43	1.40	1.05	1.60

[1] $\overline{X}$ = Mean of 6 samples

Appendix IX. Individual soluble protein percentages of fresh ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	10.50	9.45	10.20	9.75	9.15	8.40
	12.00	12.30	13.05	11.70	10.65	9.30
Tues.	10.50	9.75	9.38	9.90	9.30	9.30
	11.40	9.00	10.05	8.70	7.20	9.75
	10.80	9.30	13.05	10.35	9.75	10.05
	11.10	9.00	11.10	10.80	8.88	10.95
$\overline{X}$ [1]	11.05	9.75	11.24	10.20	9.16	9.63
	13.96	10.81	11.41	11.41	11.82	10.06
	10.50	10.05	10.95	10.50	9.30	10.88
Fri.	11.40	11.40	12.00	9.60	8.25	9.30
	10.35	6.75	9.00	8.40	7.95	9.00
	12.45	11.10	11.25	13.05	10.05	10.80
	9.60	8.58	10.80	10.50	9.30	10.05
$\overline{X}$	11.38	9.78	10.90	10.58	9.45	10.02

[1] $\overline{X}$ = Mean of 6 samples

Appendix X. Individual Iodine numbers of ground beef samples obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	49.19	52.54	47.06	47.14	45.77	48.85
	50.04	50.25	48.03	48.06	43.88	50.19
Tues.	51.09	50.44	48.68	49.17	47.58	48.51
	53.58	51.80	48.36	50.88	45.01	46.94
	49.42	48.45	51.06	48.18	45.53	47.35
	47.74	47.43	46.57	44.56	43.73	50.35
$\overline{X}$ [1]	50.18	50.02	48.29	48.00	45.25	48.70
	51.10	51.20	51.50	50.20	49.60	50.80
	51.92	50.13	49.18	51.71	49.02	51.06
Fri.	50.30	48.92	48.75	50.75	46.12	47.90
	52.60	59.52	47.78	48.41	46.04	47.65
	47.56	48.39	46.93	47.82	44.67	47.26
	48.95	50.25	46.69	52.08	44.18	50.09
$\overline{X}$	50.40	49.74	48.47	50.16	46.60	49.13

[1] $\overline{X}$ = Mean of 6 samples

Appendix XI. Individual prices per pound of fresh ground beef obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	.49	.49	.53	.49	.49	.55
	.49	.49	.49	.49	.39	.39
Tues.	.49	.50	.53	.49	.39	.55
	.49	.49	.55	.49	.39	.55
	.49	.49	.55	.49	.39	.55
	.49	.49	.55	.49	.39	.55
$\overline{X}$ [1]	0.49	0.49	0.53	0.49	0.41	0.52
	.49	.49	.49	.49	.49	.55
	.49	.49	.49	.49	.39	.43
Fri.	.53	.49	.49	.49	.39	.55
	.49	.49	.45	.49	.39	.55
	.49	.49	.55	.49	.39	.55
	.53	.49	.55	.49	.39	.55
$\overline{X}$	0.50	0.49	0.50	0.49	0.41	0.53

[1] $\overline{X}$ = Mean of 6 samples

Appendix XII. Individual prices per pound of protein of fresh ground beef obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
Day	I	II	III	IV	V	VI
	3.44	3.32	3.47	3.62	3.81	3.71
	2.96	3.18	2.95	2.89	3.00	2.54
Tues.	2.97	3.24	3.21	3.26	2.61	3.40
	2.88	3.32	3.44	4.05	3.18	3.61
	2.92	3.45	2.86	2.76	2.90	3.40
	2.86	3.45	3.54	2.93	3.06	3.61
$\overline{X}$ [1]	3.01	3.33	3.25	3.25	3.09	3.38
	2.56	3.37	3.29	3.18	2.86	3.67
	2.88	2.92	2.83	3.04	2.04	2.51
Fri.	3.03	2.81	2.91	3.95	2.74	3.63
	2.79	3.86	2.80	2.75	2.72	3.30
	3.04	3.69	3.10	2.82	3.03	3.16
	3.13	3.83	3.58	3.32	2.78	3.64
$\overline{X}$	2.91	3.41	3.09	3.18	2.70	3.32

[1] $\overline{X}$ = Mean of 6 samples

Appendix XIII. Individual prices per pound of soluble protein of fresh ground beef obtained from six Corvallis stores.

	Store Designation					
	Chain			Independent		
	I	II	III	IV	V	VI
Day						
	4.67	5.19	5.29	5.03	5.36	6.55
	4.08	3.98	3.75	4.19	3.66	4.19
Tues.	4.67	5.13	5.65	4.95	4.19	5.91
	4.30	5.44	4.47	5.63	5.42	5.65
	4.54	5.27	4.03	4.73	4.00	5.47
	4.41	5.44	5.45	4.54	4.39	5.02
$\overline{X}$ [1]	4.45	5.08	4.77	4.85	4.50	5.47
	3.51	4.53	4.29	4.29	4.15	5.47
	4.67	4.88	4.47	4.67	4.19	3.95
Fri.	4.65	4.30	4.08	5.10	4.73	5.91
	4.73	7.26	5.00	5.83	4.91	6.11
	3.94	4.41	4.89	3.75	3.88	5.09
	5.52	5.71	5.09	4.67	4.19	5.47
$\overline{X}$	4.50	5.18	4.64	4.72	4.34	5.33

[1] $\overline{X}$ = Mean of 6 samples