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Received for review January 29, 1985. Revised manuscript received September 3, 1985. Accepted November 7, 1985.

Nutrient Composition of Retail Ground Beef

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In the U.S. 24% of all beef consumed is in the form of ground beef. Retail ground beef samples selected from 10 major cities representing five geographic regions were analyzed for protein, fat, and moisture by near-infrared reflectance (near-IR) spectroscopy and by traditional methods and for inorganic nutrients by atomic absorption spectroscopy (AAS). These data indicated large variability (coefficient of variation 14–27%) in the total fat content within various generic types. With regard to accuracy and precision, the near-IR technique compared favorably to traditional techniques in the analysis of fat and moisture. The accuracy of the near-IR for protein determination will require further study.

INTRODUCTION

In 1981, the per capita consumption of ground beef was 18.6 lbs, an increase of 1.9 lbs per capita since 1971. While total beef consumption has declined steadily since 1971, the consumption of ground beef has continue to increase. Ground beef accounts for 24% of all beef consumed, an increase of 4% since 1971 (American Meat Institute, 1982). Approximately 50% of all ground beef is purchased at the retail store and consumed in the home.

Ground beef is a formulated product prepared on a regional or local basis; the extent of variability in its nutrient composition is unknown. U.S. Department of Agriculture (USDA) regulations apply only to ground beef that is prepared in federally inspected establishments. USDA regulations state that "chopped beef" or "ground beef" shall consist of chopped fresh and/or frozen beef without the addition of beef fat as such, shall not contain more than 30% fat, and shall not contain added water, phosphates, binders, or extenders. Additional statements discuss the use of seasonings and limits on the use of beef cheek meat (9CFR319.115, 1983). Heart meat and tongue meat are not acceptable ingredients in chopped beef, ground beef, or hamburger (Hibbert, 1981). State or local government regulations or guidelines determine what the levels of fat should be in a ground beef product prepared at the retail site. In many cases the regulation or guideline is equivalent to the federal standard for ground beef. Labels such as "lean" and "extra lean" may be used on ground beef if the product has significantly less fat than expected in a similar product (Hibbert, 1984). State or local government regulations or guidelines determine what the levels of fat should be in a ground beef product prepared at the retail site. In many cases the regulation or guideline is equivalent to the federal standard for ground beef.

In general, ground beef that is labeled as prepared from a specific cut such as ground chuck is fabricated from that cut and adjusted to a fat level according to the policies of individual chains. In the retail trade, various cut designations seem to be synonymous with certain generic designations based on fat level. One chain may label according to the specific cut used while another may label according to relative fat content. These are ground chuck and lean ground beef; ground round and extra lean ground beef; and ground round and extra lean ground beef. Sometimes ground sirloin is considered to be similar to extra lean ground beef. Hamburger and regular ground beef are considered to be similar.

A telephone survey of the predominant grocery chains in 10 cities indicated that approximately half of those surveyed process ground beef at the warehouse level. Coarsely ground bulk products corresponding to the generic names are shipped to individual stores where they are reground with added meat trimmings free of visible fat and repackaged for retail sale. Ground beef prepared at the warehouse level is usually tested at intervals for fat content. Infrequent monitoring may or may not be done at the store level and is dependent upon the policies of specific chains. The other half of those chains surveyed prepare ground beef at the store level. Company guidelines are general and may be equivalent to the USDA standard or a slightly lower maximum total fat value. Some stores reported that their maximum value for total fat was 25 or 27% to ensure compliance with a state or local regulation or guideline for permissible maximum fat level. The formulation of the retail product was determined by a combination of the experience of the meat cutter within each store and product standards endorsed by chain managers. In some cases sporadic on-site checks of fat level were made by the district manager or his representative.

To obtain accurate and precise nutrient data that characterize a frequently consumed product, it is necessary to evaluate the inherent variability in that product. This is an important aspect of food composition studies that is often overlooked. This study was conducted to evaluate the sources and extent of variance in the nutrient composition of uncooked ground beef sold at the retail level in the U.S. The mean concentrations of protein, fat, ash,

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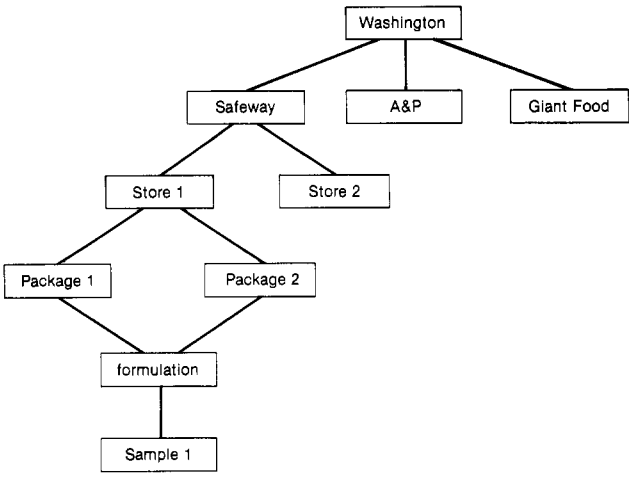

Figure 1. Preliminary sampling design for Washington area.

moisture, and inorganic nutrients (Fe, Cu, Zn, Mg, Mn, Ca, K, Na) for the different types of ground beef were determined as were the sources and extent of variance for those mean values. Data will be used to update nutrient composition data for ground beef to be reported in the revised Handbook No. 8, Composition of Foods, Beef Products.

MATERIALS AND METHODS

Objectives. *Phase 1—Preliminary*: to estimate local variability (within product types, within chains, and across the product type) of all ground beef and to validate the use of near-infrared reflectance (near-IR) spectroscopy for the determination of moisture, protein, and fat in ground beef; to establish protocol for sample handling to be used during nationwide sampling.

Phase 2—Nationwide: to estimate mean concentrations of protein, fat, moisture, ash, and inorganic nutrients for the different designations of ground beef and to evaluate the nationwide variability for these nutrients.

Sampling Design. *Phase 1*: Ground beef samples were purchased from three major grocery chains each in the Washington and Baltimore metropolitan areas. Together the three chains account for approximately 76% of the supermarket sales in each area (SN, 1983). All available types of ground beef except mixtures of beef with other meats and beef with soy were purchased in duplicate from one store for each chain in each area (Figure 1). The duplicate packages within each store were combined to form a sample. Three additional samples from two chains permitted extension of the range of previously determined near-IR calibrations for beef (Lanza, 1983). A total of 30 samples were prepared.

Phase 2: The sampling design was a broad-based nationwide sampling scheme (Figure 2). Statistically based sampling techniques that incorporated pertinent demographic information were used to develop a multistage cluster sampling plan (Cochran, 1977). Samples were purchased in five regions of the U.S. Two cities, ranking highest in supermarket sales within each region, were selected for a total of 10 cities (SN, 1983). Within each city the leading supermarket chains were chosen to account for approximately 50% of the markets' grocery store sales (Table I) (SN, 1983). Within each store two ($1^1/_2$-2-lb-weight) packages of each available type were purchased. Agents were instructed to purchase samples of each of the various types of ground beef available within the designated retail stores in each city. Although data were not intentionally weighted, the purchase of available samples seemed to be an indication of the sales volume of the various generic types. Verbal communication with various

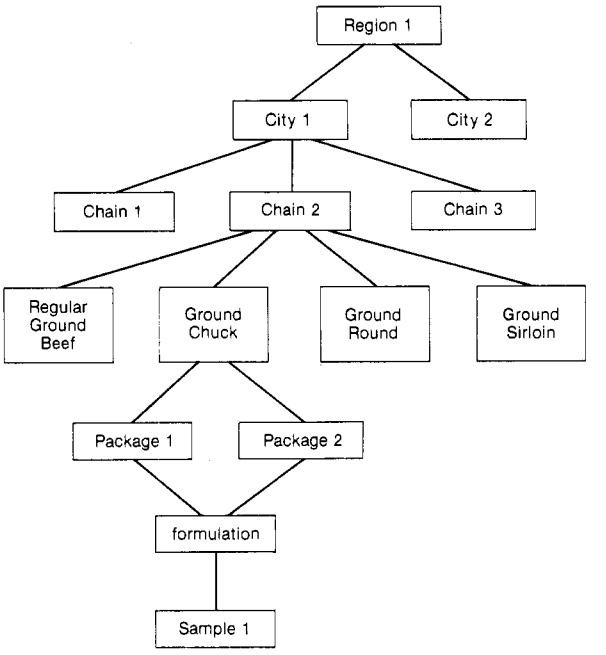

Figure 2. Sampling design for one of five regions.

Table I. Regions, Cities, and Supermarket Chains Sampled during Nationwide Sampling Phase

region	supermarket chain[a]
Northeast	
Boston (8[b])	Star Market
	Stop n' Shop
New York (2)	Waldbaum's
	Shop Rite
	Grand Union
	Foodtown
	Pathmark
Southeast	
Atlanta (14)	Alterman's
	Kroger
	Colonial
Tampa (15)	Kash n' Karry
	Winn Dixie
North-Central	
Chicago (3)	Jewel
	Dominick's
Detroit (4)	Chatham
	Kroger
	Farmer Jack
Southwest	
Houston (6)	Kroger
	Weingarten
Dallas (10)	Safeway
	Tom Thumb
	Minyards
West	
Los Angeles (1)	Von's
	Ralph's
	Alpha-Beta
San Franciso (7)	Lucky
	Safeway

[a] The various chains selected represented the major retail grocery sources in each city. [b] Rank by supermarket sales, 1980 (Source: SN Distribution Study of Grocery Store Sales, 1983).

chains indicated that regular ground beef was sold in the largest volume. In some cities, more specifically, in some chains within cities, ground beef by cut designation is more frequently sold than ground beef labeled according to degree of leanness. All types are not available in all cities or stores. A total of 100 samples were prepared for analysis. Three samples, two of chili meat and one of a ground beef soy mixture, were omitted during statistical analysis.

Table II. Wavelengths Selected and Statistical Summary of Ground Beef Analysis by Near-Infrared Spectroscopy

component	wavelengths[a]	r	SEE[b]	SEP[c]	SEP[d]
moisture	1786/1586	0.996	0.420	0.496	0.587
protein	2174/1610	0.984	0.288	0.317	0.373
fat	1724/1316	0.998	0.318	0.331	0.358

[a] λ/λ refer to wavelengths selected for the calibration equation. [b] Standard error of estimate. [c] Standard error of prediction, $n = 10$ (phase 1). [d] Standard error of prediction, $n = 13$ (phase 2).

Sample Preparation. *Phases 1 and 2*: Equal weights of two packages of the same type within each store were combined to form a sample of uncooked ground beef. Samples were reground in the Robot-Coupe food processor (Model R-6) for 45 s at 1500 rpm. Temperatures were monitored during processing and kept below 30 °C to minimize destruction of nutrients. Sample portions were stored in 4-oz screw-top polyethylene cups and held frozen at −20 °C until analyzed.

Analytical Methods. In both phases moisture (volatiles) was determined by microwave moisture analysis immediately after homogenization to determine the moisture content of the fresh product (CEM, 1979). Moisture levels for a limited number of samples were determined by oven drying (AOAC, 1980). The number of samples needed to detect a significant difference between the results for traditional methods and the near-IR method was calculated, using eq 1 and preliminary estimates of the variance for specific nutrients (Sokal and Rohlf, 1981).

Phase 1: Analyses of up to 30 ground beef samples by traditional wet chemistry methods were conducted to provide the data for the adjustment of near-IR equations. Previously reported near-IR calibration equations for beef (Lanza, 1983) were adjusted to accommodate the lower moisture and higher fat content of ground beef. Moisture (volatiles) ($n = 30$) was determined by oven drying (AOAC, 1980); total fat ($n = 11$) was determined by chloroform–methanol extraction (Folch et al., 1957) as modified by Slover et al. (1980). Since the previous calibration for protein in meat was considered less than optimum, a new calibration equation for protein in ground beef was attempted. Protein ($n = 30$) was calculated from total nitrogen as determined by macro Kjeldahl (AOAC, 1980). In order to validate the new near-IR calibration for beef, the moisture, protein, and fat for 10 different ground beef samples were then determined by near-IR and compared to their wet chemistry values. Near-IR analysis was carried out according to the procedures recently described by Lanza (1983). The Pacific Scientific Model 6350 scanning spectrocomputer (Pacific Scientific, Silver Spring, MD) was used. Each sample was packed into a standard Pacific Scientific quartz sampling cup (approximately 30 g of meat). The sample was scanned 50 times from 1100 to 2500 nm, and the data were stored as log $(1/R)$ (R = reflectance). Optimum wavelengths for the prediction of components by near-IR were determined by multiple linear regression analysis of the second derivatives of log $(1/R)$ using standard software for the Model 6350 (Table II). Finally, total fat values for the 30 phase 1 (local sampling) samples were determined by near-IR.

Phase 2: By the calibration equations for moisture, protein, and fat that were determined in phase 1, the 96 samples purchased nationwide were analyzed by near-IR. A total of 13 samples representing the range of fat levels to be sampled were selected and analyzed by wet chemistry methods to permit the calculation of the standard error of prediction (SEP).

The following statistical formula (1) was used to determine the minimum number of samples to be analyzed in phase 2 (nationwide sampling) by each of two techniques to permit statistical comparisons (Sokal and Rohlf, 1981),

$$n \geq 2(\sigma/\delta)^2[t_{\alpha[\nu]} + t_{2(1-P)[\nu]}]^2 \quad (1)$$

where n = number of replications, σ = estimate of standard deviation, δ = the smallest true difference that is desired to detect, ν = degrees of freedom of the sample standard deviation, α = significance level (such as 0.05), P = desired probability that a difference will be found to be significant (if it is as small as δ; the intended power of the test), and $t_{\alpha[\nu]}$ and $t_{2(1-P)[\nu]}$ = values from a two-tailed t-table with ν degrees of freedom and corresponding probabilities of α and $2(1 - P)$, respectively.

In order to estimate mean values for the nutrients of interest, numbers of samples required were calculated according to the statistical formula (Cochran, 1977)

$$n \geq [tS/rY]^2 \quad (2)$$

where n = number of samples, t = the abscissa of the normal curve that cuts off an area of α at the tails, r = relative error in the estimated population mean, s = standard error of the estimate, and Y = an estimate of the population mean determined by a pilot study.

In addition, regression techniques were used to evaluate the relationship between the two methods (SAS Institute, 1982).

Inorganic nutrients for the 100 samples were determined by atomic absorption spectrophotometry (AAS) using a wet-ash procedure with nitric acid and hydrogen peroxide (Wolf, 1981). Ash was determined by a commercial laboratory on limited numbers of samples (AOAC, 1980). Analyses of variance were conducted to determine the effects of region and generic type on nutrient values in ground beef (SAS Institute, 1982).

Table III. Nutrient Means, Coefficients of Variation, Ranges, and Percent Contribution to U.S. RDA in Retail Ground Beef Purchased in Baltimore and Washington

nutrient[a]	mean[b]	CV,[c] %	min–max	U.S. RDA, %
protein, g	18.1	8.46	15.5–20.8	39.8
total fat, g	20.0	30.9	9.51–29.0	
moisture, g	60.5	8.39	52.3–68.8	
iron, mg	1.84	10.6	1.19–2.15	10.0
zinc, mg	3.87	14.4	2.06–4.66	25.5
magnesium, mg	17.5	14.1	9.80–22.3	4.3
sodium, mg	67.6	13.5	42.9–99.2	2–6[d]
potassium,[e] mg	249.5	13.6	198.7–324.0	4.3–12.9[d]
copper, mg	0.072	28.5	0.055–0.166	3.6
manganese, mg	0.018	43.4	0.006–0.032	0.4–0.8[d]
calcium, mg	7.69	39.9	4.07–16.1	0.8

[a] Amount per 100 g of uncooked ground beef. [b] $n = 27$. [c] Coefficient of variation for grand mean, includes all sources of variability except variance due to analytical replicates. [d] Percentage of estimated safe and adequate daily dietary intakes of selected vitamins and minerals (NRC, NAS, 1980). [e] $n = 26$.

RESULTS AND DISCUSSION

Phase 1. We evaluated the sources and extent of variance for nutrients present in retail ground beef. Table III gives the preliminary study (Baltimore, Washington) mean values, coefficients of variation (CV), minimum, maximum, and percent of the U.S. RDA for each nutrient calculated across all generic types (21CFR101.9(7) (iv), 1985). A 100-g uncooked portion of ground beef is a good source of protein (32% of the U.S. RDA), iron (18% of the U.S. RDA), and zinc (26% of the U.S. RDA). In addition, it is relatively low in sodium, a nutrient of concern to certain sectors of the population. Ground beef is not considered to be a good source of copper, manganese, and calcium. The large variance in these values can be partially

Table IV. Nutrient Means by Generic Type for Ground Beef Samples Purchased in Baltimore and Washington

nutrient	generic type					
	regular (n = 8)	lean (n = 4)	chuck (n = 4)	round (n = 4)	extra-lean (n = 6)	av CV,[a] %
protein,[b] g	16.6	17.6	18.7	19.6	19.4	5.56
total fat, g	25.9	22.5	17.1	15.6	15.1	19.1
moisture, g	55.2	58.4	63.5	65.6	64.76	4.40
iron, mg	1.70	1.79	1.83	1.93	2.01	8.42
zinc, mg	3.42	4.19	3.92	4.05	4.06	10.8
magnesium, mg	15.3	17.0	18.2	19.5	19.6	8.7
sodium, mg	65.9	68.0	63.7	74.1	66.8	12.0
potassium, mg	213.9	244.4	264.7	283.6	276.0	10.4
copper, mg	0.062	0.092	0.074	0.070	0.076	17.5
manganese, mg	0.015	0.022	0.019	0.023	0.017	41.0
calcium, mg	7.88	9.96	8.25	7.70	5.91	40.1

[a] Arithmetic, unweighted average of coefficients of variation (CV's) for the various types. [b] Amount per 100 g of uncooked ground beef.

attributed to the low levels of occurrence and subsequent analytical limits of detection. The variability in fat levels can be partially attributed to differences in the formulation of various generic types (i.e., regular, lean, and extra-lean, etc.) by different chains. Coefficients of variation for protein (8.5%), moisture (8.4%), iron (10.6%), zinc (14.4%), magnesium (14.1%), sodium (13.5%), and potassium (16.9%) are moderate relative to those for total fat (30.9%) despite differences in formulation practices.

Table IV shows the preliminary study (Baltimore, Washington) nutrient means for the various generic types familiar to the consumer and the arithmetic average of CV's for the various types. One can see that within generic type manganese, copper, and calcium are still highly variable. Except for calcium the average CV for nutrient means for the various generic types is less than the CV calculated across all samples (Tables III and IV). While the average CV for total fat (19.1%) is less, it is still sizeable considering the levels of total fat found in ground beef.

Phase 2. A comparison of the mean nutrient levels across all types of uncooked retail ground beef sampled nationwide in this study and mean nutrient levels listed in Handbook No. 8 (Watt and Merrill, 1963) and in McCance and Widdowson's *The Composition of Foods* (Paul and Southgate, 1978) appears in Table V. In general, nutrient levels from this study compare favorably with nutrient levels given by other sources (Watt and Merrill, 1963; Paul and Southgate, 1978). However, the iron level (1.82 mg/100 g) is considerably lower than that reported by other sources. Iron values for beef and for ground beef, in particular, have been reevaluated in view of the results of an extensive beef study conducted as a collaborative effort between the National Livestock and Meat Board and the USDA (Wolf and Ono, 1980). In that study of 175 carcasses and 14 cuts, the mean iron value for uncooked beef, separable lean, was 2.2 ± 0.5 mg/100 g (compared to 3.2 mg/100 g in Handbook No. 8). Assuming the dilution effect of higher fat levels resulting from the formulation of ground beef, this study of ground beef confirms the observed differences in iron values. These new values for cooked and uncooked beef will be included in the revised Handbook No. 8 section for beef. The mean total fat level in this study (21.6 g/100 g) is considerably higher than the levels (15.5 g/100 g and 16.2 g/100 g) listed by Handbook No. 8 (Watt and Merrill, 1963) and by Paul and Southgate, respectively. The Handbook No. 8 value, 15.5 g/100 g, was obtained by taking the mean of lean and regular ground beef values. The mean total fat value, 27.4 g/100 g, for regular ground beef in this study is higher than the value of 21.2 g/100 g stated in Handbook No. 8. Further pertinent details concerning the Paul and Southgate values for beef, (mince, raw) are not given. Marchello et al. (1984) reported a mean fat level of 16.0 g/100 g for ground beef fabricated in a laboratory setting from carcass beef. However, it is difficult to relate their value to the mean value of total fat in retail ground beef.

Table V. Comparison of the Nutrient Means for Uncooked Retail Ground Beef from Nationwide Sampling

nutrient[a]	phase 2 (n = 96)	handbook, #8[b]	McCance and Widdowson[c]
protein, g	17.6	17.9, 20.7	18.8
total fat, g	21.6	21.2, 10.0	16.2
moisture, g	59.7	60.2, 68.3	64.5
ash, g	0.83	0.7, 1.0	
iron, mg	1.77	(2.7, 3.1)[d]	2.7
zinc, mg	3.88	3.4[e]	4.3
copper, mg	0.076		0.15
magnesium, mg	17.7	17, 21	17.0
sodium, mg	68.5		86.0
potassium, mg	262.0	236	290.0
manganese, mg	0.015		

[a] Amount per 100 of uncooked ground beef. [b] Regular and lean grinds as listed in Watt and Merrill (1963). [c] Beef, mince, raw. [d] Recognized as questionable by Nutrient Data Research Group, HNIS, USDA. [e] Murphy, Willis, and Watt, 1975.

The extent of variation in total fat level that occurs within generic type is of considerable interest (Table VI). Coefficients of variation are generally less than 10% for those nutrients that occur in significant (>5% U.S. RDA per 100-g portion) amounts. However, CV's for fat were 13.6–28%.

An analysis of variance (ANOVA) for total fat across all samples in phase 2 confirmed that generic types were significantly ($p < 0.0001$) different by total fat content found in raw beef. A Duncan's multiple-range test (MRT) on the main effect, generic type, revealed that regular ground beef and lean ground beef were statistically similar. However, lean ground beef was also statistically similar to ground chuck, attributable to the overlap in values. Ground sirloin, extra lean ground beef, and ground round clustered together.

Table VII contains the nutrient means and standard deviations for the various clusters based on total fat levels that were determined in the nationwide sampling data. Regular ground beef was considered to be a cluster. Lean ground beef was grouped with ground chuck since their respective ranges were similar. Ground sirloin, extra-lean ground beef, and ground round were included in a third cluster. An ANOVA for total fat across the three clusters (arbitrarily named regular, lean, and extra-lean) substantiated significant ($p < 0.0001$) differences among clusters. The mean total fat level and standard deviations, respectively, for regular (27.4%, 3.71%), lean (22.1%, 4.08%), and extra-lean (16.6%, 4.39%) indicate discrete

Table VI. Nutrient Means and Standard Deviations for Generic Types of Ground Beef from Nationwide Sampling

nutrient[a]	regular (n = 30)	lean (n = 6)	chuck (n = 21)	round (n = 24)	extra-lean (n = 8)	sirloin (n = 6)
protein, g						
mn	16.2	16.7	17.7	18.7	18.8	18.9
std	1.05	1.28	0.99	1.21	1.06	0.59
total fat, g						
mn	27.4	24.2	21.5	16.7	16.7	16.3
std	3.72	5.09	3.67	4.66	4.37	3.99
moisture, g						
mn	56.3	58.2	60.2	64.1	63.5	63.7
std	2.29	3.22	2.64	4.18	3.28	2.92
ash,[b] g						
mn	0.67	0.90	0.80	1.10	0.90	
std	0.058	0.141	0.082		0.0	
iron, mg						
mn	1.69	1.70	1.75	1.88	1.81	1.89
std	0.162	0.182	0.192	0.231	0.180	0.084
zinc, mg						
mn	3.58	3.56	3.84	4.19	4.27	4.16
std	0.336	0.392	0.370	0.457	0.905	0.404
copper, mg						
mn	0.061	0.062	0.071	0.111	0.067	0.070
std	0.0059	0.0086	0.019	0.187	0.011	0.007
Magnesium, mg						
mn	15.6	18.5	17.8	19.6	18.7	19.7
std	1.71	4.79	2.23	2.66	2.79	1.71
sodium, mg						
mn	68.6	70.8	69.7	68.1	67.4	62.6
std	8.54	5.13	5.55	6.26	7.66	5.87
potassium, mg						
mn	232.0	268.0	265.0	281.0	292.0	302.0
std	23.5	24.8	19.1	33.6	34.7	26.1
manganese, mg						
mn	0.016	0.010	0.014	0.018	0.013	0.015
std	0.007	0.004	0.006	0.008	0.008	0.009

[a] Amount per 100 g of uncooked ground beef. [b] n = 3. [c] n = 1.

Table VII. Nutrient Means and Standard Deviations for Clustered Ground Beef Data from Nationwide Sampling

	regular[b] (n = 31)		cluster lean[c] (n = 27)		extra-lean[d] (n = 38)	
nutrient[a]	mean	SD	mean	SD	mean	SD
protein, g	16.2	1.00	17.5	1.12	18.9	1.08
total fat, g	27.3	3.71	22.1	4.08	16.6	4.39
moisture, g	55.3	2.62	59.2	2.89	63.6	3.43
ash, g	0.67	0.6[e]	0.83	0.10[f]	0.95	0.10[g]
iron, mg	1.68	0.16	1.74	0.19	1.87	0.20
zinc, mg	3.58	0.33	3.78	0.38	4.20	0.55
magnesium, mg	15.7	1.70	17.9	2.72	19.4	2.53
sodium, mg	68.7	8.40	70.0	5.39	67.2	6.60
potassium, mg	232.0	23.5	265.0	20.0	287.0	32.9
copper, mg	0.06	0.01	0.07	0.02	0.10	0.15
manganese, mg	0.02	0.01	0.01	0.01	0.02	0.01
calcium, mg	8.71	2.72	7.86	3.68	6.76	2.12

[a] Amount per 100 g of uncooked ground beef. [b] Includes only regular ground beef. [c] Includes ground lean, ground chuck. [d] Includes ground round, ground sirloin, extra-lean ground beef. [e] n = 3. [f] n = 6. [g] n = 4.

clusters or groups that are relevant to users of nutrient composition data.

An ANOVA for total fat values by region across all generic types indicated a significant regional variation ($p < 0.025$). For all ground beef, samples from the North-Central area of the U.S., represented by Chicago and Detroit, were significantly higher in fat than samples from all other regions.

Mean Total Fat Values for All Samples by Region

region	N	mean
North-Central	20	25.0[a]
Southeast	23	21.8[b]
West	19	20.4[b]
Northeast	22	20.4[b]
Southwest	22	20.2[b]

[a,b] Mean values with the same letter are not significantly different.

Within generic types, the differences as determined by an ANOVA of region followed by the Duncan's multiple-range test indicated that ground chuck and ground round from the North-Central region were significantly higher in fat than those products from other regions. Numbers of extra-lean and regular ground beef samples were too small to permit within generic type comparisons. Lean ground beef was not available in two regions at the time of sample pick-up; therefore, conclusions concerning the effect of region for this type cannot be made. The range of mean total fat values by region within each type is large (regular, 24.5–29.7; lean, 19.4–27.8; extra-lean, 13.4–24.3; round, 11.3–20.9; sirloin, 14.3–21.2; chuck, 18.6–25.0). In view of the fact that fat provides 9 kcal/g, a range of 5–10 g of total fat/100 g of ground beef means a difference of 45–90 cal per 100-g portion of the raw product, assuming none is lost in cooking. This difference may be most important when the ground meat is used in mixed dishes without browning

and removing fat that liquefies.

When ANOVAs were run across clusters, region continued to be a source of significant ($p < 0.001$) variation for total fat. An ANOVA of the main effect, region, within the extra-lean cluster indicated that region was a significant ($p < 0.02$) source of variation. However, within the lean and regular clusters, region was not a significant source of variation. This pattern follows the results of the ANOVA by individual generic type. As we saw above, significant effects of region were demonstrated within ground chuck and ground round. The "clustering" of various generic types provided slightly larger numbers of observations within each group, providing a more conclusive statistical test. Again, the range of total fat values within each cluster is large: extra-lean, 3.69–24.7; lean, 15.5–32.1; regular, 20.1–33.9.

For iron levels, both cluster and region were statistically significant ($p < 0.001$) sources of variation. Duncan's MRT by cluster indicated that iron values for the extra-lean cluster were significantly different from those values for the lean and regular clusters. However, these differences seemed small and may not be nutritionally significant. Similar results were found for ANOVA across all generic types. The Duncan's MRT indicated that iron content was inversely related to mean levels of total fat. The extra-lean cluster had the highest mean iron level (1.87 mg/100 g) while the regular cluster had the lowest mean iron level (1.68 gm/100 g). Across all clusters and regions mean iron values ranged from 1.64 to 1.90 mg/100 g, a difference of 1.4% of the U.S. RDA (18 mg/day) for women. The nutritional significance of this small difference is doubtful.

For zinc, generic type was a significant ($p < 0.0001$) source of variation. The Duncan's MRT indicated the grouping of extra-lean ground beef, ground round, and ground sirloin (range 4.16–4.27 mg/100 g) on the basis of zinc values; ground chuck, regular ground beef, and lean ground beef (range 3.56–3.84 mg/100 g) were statistically similar. Region did not significantly affect the variance in zinc levels. Similar trends were noted when the ANOVA was performed on clustered data. Mean zinc levels were inversely related to cluster (i.e., fat level) just as iron values were. That is, as the fat level increases, zinc concentration decreases. The difference between the minimum and maximum mean zinc values for all types, 0.60 mg/100 g, represents 4% of the U.S. RDA (18 mg/100 g). The nutritional significance of this difference is minor.

Regression analysis of moisture, fat, and protein values determined by near-IR and by traditional methods indicated good agreement between the methods. For total fat, a comparison of the near-IR and Folch methods for ground beef showed no significant difference from an expected value of zero ($p = 0.73$) for the intercept. Furthermore, the slope of the comparison between these two methods for total fat was not significantly different from an expected value of 1.

For protein, regression analysis of the results of near-IR and Kjeldahl methods showed small but significant differences ($p = 0.04$) between the intercept (-3.8) for the two methods and "0". Although there is a negative bias apparent, the differences may not be of practical significance since the mean protein value (17.9) is much greater than zero; thus, it represents an extrapolation beyond the data. Use of the near-IR for determination of protein occurring in small amounts would have to be evaluated as a separate case. The calculated slope (1.21) for the two methods are significantly different from "1". This difference would result in an overestimation of protein by as much as 21%. The nutritional significance for the determination of protein needs further evaluation.

Regression analysis of moisture values of near-IR and AOAC methods showed no significant difference between the two methods. The slope obtained was not significantly different from an expected value of 1. In addition, the intercept was not significantly different from an expected value of zero.

The considerable variability in total fat content within generic type has important implications with regard to variability in calories contributed by ground beef in the diet as well as to the variability in dietary levels of fats. This is particularly true when ground beef is included in recipe products such as chili, casseroles, and other mixed dishes. To a lesser extent this would be true when ground beef is used to prepare meat patties that are cooked and served without draining or blotting.

Although there may be substantial difference in price per pound depending upon retail label suggestive of degree of leanness, there is little certainty that the degree of leanness will be assured. In fact, lean ground beef may be the same as regular ground beef or ground chuck. Mean values for these types would suggest greater differences between types. However, the large variance within each type and the overlapping in total fat values between types requires that ground beef to be used for research projects be formulated to precise specifications. For surveys of the fat intake of populations, one must consider this large variance. For consumers the selection of a particular designation or type will continue to be determined subjectively by cost, intended use, and sensory preferences as well as by the perception or knowledge of nutrient content (particularly fat content).

ACKNOWLEDGMENT

We gratefully acknowledge the technical assistance of Sandra G. Korth in the analysis of the ground beef samples as well as the statistical treatment of the nutrient data.

Registry No. Fe, 7439-89-6; Zn, 7440-66-6; Mg, 7439-95-4; Na, 7440-23-5; K, 7440-09-7; Cu, 7440-50-8; Mn, 7439-96-5; Ca, 7440-70-2.

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Received for review March 8, 1985. Accepted November 12, 1985. Mention of trademark or proprietary products does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply their approval to the exclusion of other products that may also be suitable.

Enzymic and Nonenzymic Factors Affecting Lipid Peroxidation in Raw Beef Muscles

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The longissimus dorsi, psoas major, semimembranosus, and semitendinosus beef muscles from steers and bulls were analyzed for ether-extractable fat, myoglobin, and nonheme iron content, microsomal enzymic lipid peroxidation activity, fiber type profile, and other properties. Each muscle was also ground and stored at 4 °C for 0 and 7 days to monitor lipid peroxidation by the thiobarbituric acid (TBA) test. For muscles from steers, microsomal enzymic lipid peroxidation activity was positively correlated with intermediate fiber number, but inversely related to ether-extractable fat content and red fiber number; for muscles from bulls, it was positively correlated with nonheme iron content, but inversely related to white fiber number. While TBA values of refrigerated, ground muscles were correlated with microsomal lipid peroxidation activity for muscles from steers, they were correlated with total pigment and myoglobin content for muscles from bulls.

INTRODUCTION

The quality deterioration of meat and meat products through lipid peroxidation is of major concern at the present time because of the increased use of precooked or convenience meat items by the food service industry and in the home. Although cooked meat is more susceptible to lipid peroxidation than uncooked meat, oxidative changes in lipids can become a serious problem for uncooked meat when it is subjected to size reduction (grinding, flaking, chunking), freeze-thawing, temperature abuses in handling and distribution, and/or prolonged storage. Also, due to the free-radical chain reaction nature of lipid peroxidation, any degree of the oxidation occurring in raw meat materials can accelerate the development of "warmed-over" flavor (the oxidized flavor) in stored, cooked meat.

The mechanisms of lipid peroxidation in cooked meat have been studied in different laboratories, with no consensus in regard to the relative role of heme iron vs. nonheme iron as the catalyst most responsible for the oxidation (Igene et al., 1979; Kwoh, 1971; Love and Pearson, 1974; Younathan and Watts, 1959). Less effort has been directed toward investigating the nature of lipid peroxidation in raw meat. However, there have been some studies implicating the meat pigment myoglobin (heme iron) as playing a direct role in lipid peroxidation in raw meat (Govindarajan et al., 1977; Greene, 1969; Hutchins et al., 1967; Verma et al., 1984). Moreover, because the oxidized meat pigment (metmyoglobin) can catalyze the peroxidation of unsaturated fatty acids in model systems (Kendrick and Watts, 1969; Kwoh, 1971; Lee et al., 1975; Rhee, 1978a) and because the extent of lipid peroxidation is highly correlated with the degree of discoloration in raw meat products (Rhee et al., 1983, 1985b), one may readily assume that heme iron catalysis can indeed play an important role in lipid peroxidation occurring in uncooked meat and meat products. In spite of the observed correlation between the two oxidative changes, it has not been directly proven that the oxidation of heme pigments causes or initiates lipid peroxidation in raw meats. Liu (1970a,b) determined the effects of pH and additives on linoleate oxidation catalyzed by metmyoglobin, a nonheme iron chelate (Fe^{2+}–EDTA), and beef homogenate and concluded, on the basis of responses to additives and pH, that the catalytic activity of beef homogenate was due to both heme iron and nonheme iron.

While lipid peroxidation in red meats generally has been regarded as a nonenzymic reaction (i.e., the reaction primarily catalyzed by nonheme iron or heme iron, or by both), our recent studies have shown the presence of an enzymic lipid peroxidation system associated with beef muscle microsomes (Rhee et al., 1984), with beef (steer) trapezius muscles having a higher activity per milligram of microsomal protein than beef (steer) longissimus dorsi muscles (Rhee et al., 1985a). The present study was conducted to determine nonenzymic and enzymic factors influencing lipid peroxidation in several different beef muscles from steers and bulls and possible interrelations among them. The factors determined in this study include

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0021-8561/86/1434-0308$01.50/0