Use of near infrared transmission for rapid analysis of meat composition

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Introduction

The meat industry routinely determines meat composition (fat, water, protein) for quality monitoring and processed product formulation. Meat, as a raw material, is extremely variable and may range from 1–65% fat, 25–80% water and 5–25% protein. Compositional analysis on a batch-by-batch basis is essential. The traditional methods (AOAC International) of greatest accuracy and precision are typically time-consuming and involve separate methods for each component (fat, water and protein). Consequently, there have been numerous rapid methods developed for use in meat composition measurements. Even these, however, usually measure only one component and the other methods are needed for the remaining components of interest.

Near infrared (NIR) technology has unique potential for applications in the meat industry because it is both rapid and capable of measuring several components simultaneously. However, it must be relatively accurate and precise as well as rugged (insensitive to operator variation) over a wide range of product composition. Ideally, such a method would be equivalent to AOAC International methods and with adequate demonstration of performance, qualify for AOAC International approval.

This study was initiated to validate the performance of NIR analysis for measurement of meat composition by comparing the results from a NIR transmission instrument to AOAC International methods for beef and pork samples over a wide range of composition.

Materials and methods

Sample selection and preparation

To provide as much variation in composition as possible, both pork and beef carcasses were selected on the basis of weight, sex and grade differences. Beef carcasses were selected in commercial plants by utilizing USDA yield grades and age differences (Table 1). One-half of each carcass was fabricated into US wholesale cuts; chuck, rib, loin, sirloin, round, brisket, plate and flank. Each wholesale cut was deboned, coarse-ground (9.5 mm), mixed, reground (3.2 mm), packaged and frozen in 0.45 kg units prior to sampling.

For pork, both barrows and gilts were selected within five live weight ranges from 82–127 kg. (Table 2). (Sows weighing over 200 kg were also included.) Pigs were selected from Iowa State University herds, slaughtered and carcasses chilled at the ISU Meat Laboratory. After chilling, one half of each carcass was fabricated into US wholesale cuts; picnic, butt, loin, belly and ham. Using the procedure outlined for beef, each cut was prepared, packaged and frozen for later use.

Before analysis, a minimum of 12 randomly selected packages (0.45 kg) from each wholesale cut were thawed at 5°C. After thawing, the packages representing each cut were combined and

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Table 1. Number of beef carcasses and types utilized for composition comparisons.

Sex	USDA yield grade		
	1–2	4–5	no-roll
Steers	4	4	—
Heifers	4	4	—
Cows	—	—	4

Table 2. Number of pork carcasses and types utilized for composition comparisons.

Sex	Live weight (kg)					
	82–91	91–100	100–109	109–118	118–127	>127
Barrows	2	2	2	2	2	—
Gilts	2	2	2	2	2	—
Sows	—	—	—	—	—	4

blended in a RoboCoupe food chopper. Samples were blended in 10 second intervals until a uniform finely chopped paste was achieved. When sample preparation was complete, portions of the mixed sample were collected for near infrared (NIR) analysis and AOAC International methods.

Sample analysis

The NIR analysis utilized a Foss Electric Meatspec. This instrument utilizes measurements of 11 wavelengths at five different points on each sample. Calibration is achieved using Partial Least Squares regression. Sample units (≈250 g) were collected and portioned into the sample holder recommended by the manufacturer as appropriate for beef and pork. At the same time, appropriate sample portions were weighed and analyzed in triplicate by AOAC International methods.[1] The methods included moisture by vacuum oven drying (AOAC 950.46), fat by ether extraction (AOAC 960.39) and protein by combustion (AOAC 992.15).

Individual measurements were entered in the Statistical Analysis System (SAS, 1991) which was used to determine the means, standard errors and analysis of variance. Least significant difference ($P < 0.05$) was used to test differences between means. Pearson correlation coefficients were used to measure the linear relationship between the two methods.

Results and discussion

The range of values encountered in this group of samples was 6.8–58.8% for fat, 31.4–72.2% for moisture and 8.9–21.0% for protein. These represent typical extremes that might be encountered for raw meat sources in the US.

The composition values of the individual wholesale cuts for beef (Table 3) and pork (Table 4) demonstrate the variation of fat deposition at different anatomical locations. While fat and protein

Table 3. Least squares means of composition (%) of wholesale cuts of beef measured by AOAC methods and NIR transmission analysis.

Cut	Method	Fat	Moisture	Protein
Brisket	AOAC	38.19	47.39	13.60
	NIT	35.49	49.69	13.82
Chuck	AOAC	21.96	60.09	17.49
	NIT	21.29	60.88	16.66
Flank	AOAC	45.64	41.15	12.62
	NIT	38.24	47.33	13.34
Loin	AOAC	29.96	53.27	16.02
	NIT	30.06	54.00	14.74
Plate	AOAC	38.13	47.25	14.00
	NIT	36.72	48.70	13.09
Rib	AOAC	30.90	52.04	15.74
	NIT	31.60	52.79	14.37
Round	AOAC	16.62	63.66	19.11
	NIT	16.76	64.13	18.14
Sirloin	AOAC	25.12	57.31	16.93
	NIT	24.75	58.18	15.80

measurements vary somewhat, the values for moisture are consistently greater when measured by NIR transmittance compared to the AOAC methods. This is reflected in the overall grand means for all samples (Table 5). Moisture content was significantly greater when measured by NIR transmittance relative to the AOAC methods. For beef, the quantitative difference in moisture measured was 1.68%; for pork, 1.42%. The measurement of fat content was not significantly different between the methods for beef and protein values for pork also showed no significant differences. On the other hand, the values for fat content of pork by the two methods were significantly different as were protein values for beef. The quantitative difference in these values were 0.70% for the protein in beef and 1.42% for fat content in pork. The standard deviations, representing the full range of values for each component, are smaller for each NIR transmittance mean than for the AOAC methods.

Calculation of correlation coefficients showed very high correlations between the NIR tranmission measurements and those by AOAC methods. Figures 1, 2 and 3 show the relationship of composition values obtained by the Meatspec and AOAC methods for beef. The correlation coefficients were 0.995 for fat, 0.992 for moisture and 0.949 for protein. Figures 4, 5 and 6 show

Table 4. Least squares means of composition (%) of wholesale cuts of pork measured by AOAC methods and NIR transmission analysis.

Cut	Method	Fat	Moisture	Protein
Belly	AOAC	42.84	44.09	12.43
	NIT	39.69	46.86	12.62
Butt	AOAC	31.97	52.90	14.42
	NIT	29.68	54.53	14.80
Ham	AOAC	21.86	60.26	19.15
	NIT	21.65	60.86	16.95
Loin	AOAC	36.40	48.68	14.22
	NIT	35.46	50.15	13.99
Picnic	AOAC	21.51	60.85	16.86
	NIT	20.72	61.49	16.95

Table 5. Overall means and standard deviations obtained for all samples analysed by AOAC methods and NIR transmission analysis.

		Fat	Moisture	Protein
Beef	AOAC	$30.82^{a} \pm 12.93$	$52.77^{b} \pm 10.05$	$15.69^{a} \pm 2.93$
	NIT	$29.36^{a} \pm 11.33$	$54.45^{a} \pm 8.84$	$14.99^{b} \pm 2.70$
Pork	AOAC	$30.91^{a} \pm 9.46$	$53.36^{b} \pm 7.45$	$15.42^{a} \pm 6.89$
	NIT	$29.49^{b} \pm 8.41$	$54.78^{a} \pm 6.52$	$15.06^{a} \pm 1.92$

[a,b]means with the same letters within a column for one species (pork or beef) are not different.

the corresponding values for pork, with the correlation coefficients being 0.984 for fat, 0.987 for moisture and 0.957 for protein. Correlation coefficients have been previously reported to be lower for protein in meat than for fat or moisture when measured by NIR transmittance and reference methods.[2]

Conclusions

The NIR transmission measurements with the Meatspec instrument showed very high correlation coefficients relative to AOAC methods, particularly for fat and moisture.

Although the differences between NIR transmission measurements and the AOAC method for moisture were statistically significant, the close correlation indicates that applications to the meat

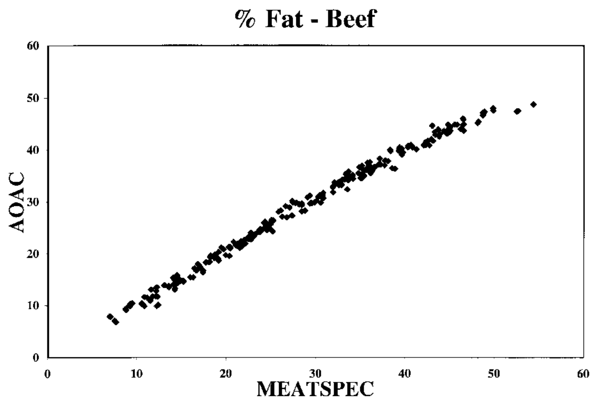

Figure 1. Analytical values for % fat in beef using AOAC International methods and NIR transmission (Meatspec).

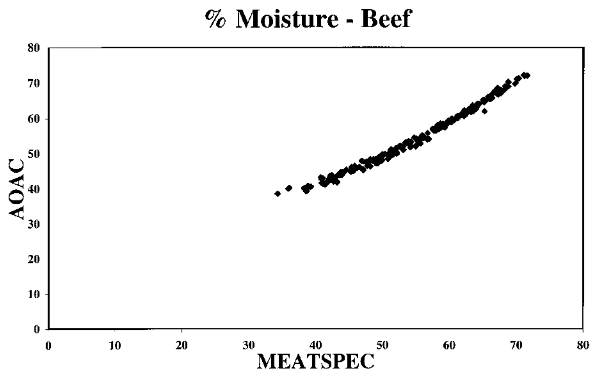

Figure 2. Analytical values for % moisture in beef using AOAC International methods and NIR transmission (Meatspec).

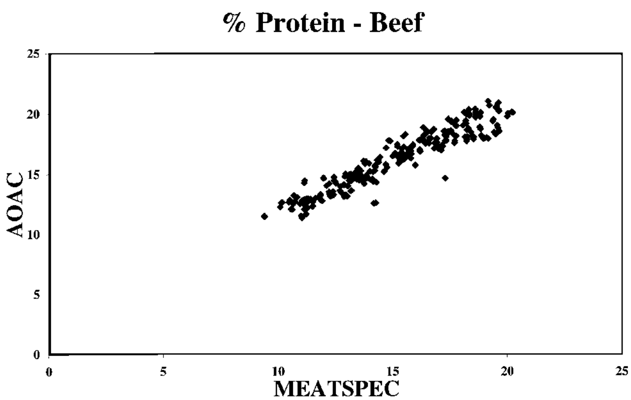

Figure 3. Analytical values for % protein in beef using AOAC International methods and NIR transmission (Meatspec).

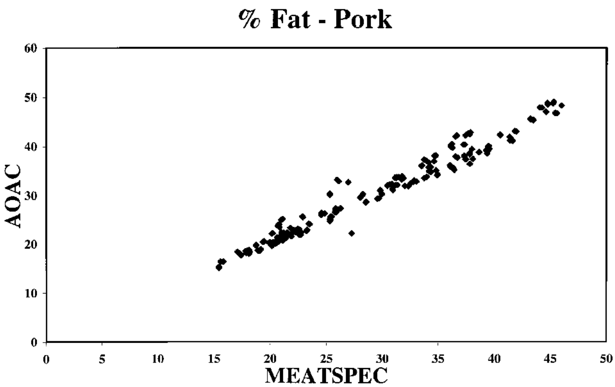

Figure 4. Analytical values for % fat in pork using AOAC International methods and NIR transmission (Meatspec).

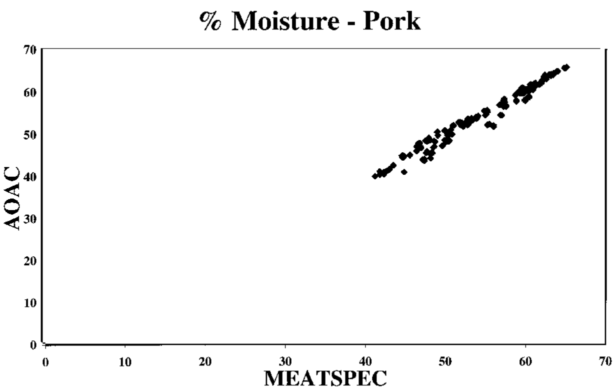

Figure 5. Analytical values for % moisture in pork using AOAC International methods and NIR transmission (Meatspec).

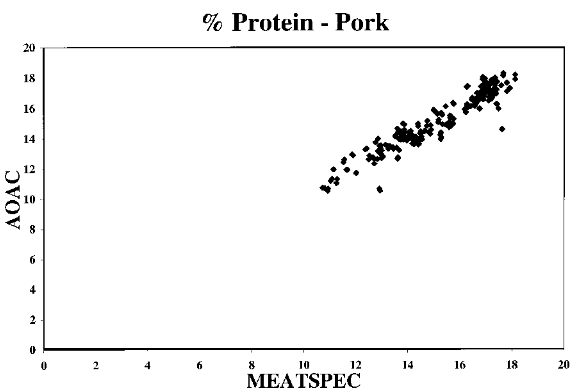

Figure 6. Analytical values for % protein in pork using AOAC International methods and NIR transmission (Meatspec).

industry would be very useful. The advantages of time savings and multi-component analysis offered by the NIR transmission measurement are major considerations for the meat industry.

References

1. AOAC, *Official Methods of Analysis* (15th Edn). Association of Official Analytical Chemists Inc., Arlington, Virginia (1990).
2. H. Berg and K. Kolar, *Fleishwirtsch* **71(7),** 787 (1991).