January 2003

Cow Muscle Profiling: Processing Traits of 21 Muscles from Beef and Dairy Cow Carcasses

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Beef and dairy cow carcasses exhibited considerable variation in muscle processing traits. These results suggest opportunities may exist to enhance the value of selected muscles.

Summary

Twenty-one muscles from beef and dairy cow carcasses were analyzed for objective color, shear force, pH, expressible moisture, total collagen, total heme-iron and proximate composition. Results of this analysis showed large variation in processing traits from muscle to muscle. Muscle traits were most often influenced by fat thickness in both beef and dairy carcasses. These results will aid in selecting muscles that are well suited for enhancement.

Introduction

Previous research has revealed 43% of the cow carcass is sold as boxed beef. Much of the remaining 57% is merchandised as beef trim for grinding and processing. To increase the overall value of the cow carcasses it is necessary to characterize the muscles harvested from these animals. Cows of advanced maturities will yield meat with differing chemical and physical properties that directly influence its processing potential. Information about muscles from these animals was not readily available before this study. The lack of information has lead to the underuse of muscles from dairy and beef cows. Therefore, the objectives of this study were to create a database of information, to include processing traits of 21 muscles from beef and dairy cow carcasses and to determine effects of carcass weight, fatness, muscling level and skeletal maturity on these traits.

Procedure

One hundred and forty-five cow carcasses (74 beef and 71 dairy) were selected over a 5-month period in four geographic locations (Green Bay, Wis., Gering, Neb., Phoenix, Ariz., and Gainesville, Fla.). Carcasses were selected based on estimated 12th rib fat thickness (< .10 in > .10 in), carcass weight (< or > 550 lb for beef and < or > 750 lb for dairy), muscling level (heavy/ medium or light) and skeletal maturity (USDA C/D or E score). Approximately five carcasses were selected within each cell, from which 21 muscles per carcass were harvested for analysis. Muscles from two carcasses were evaluated for objective color using a Hunter Lab® Mini Scan XE plus colorimeter with a 1-inch port, and for Warner-Bratzler shear force (dry heat cooked to 71^{o}C, 0.5-inch cores). Chemical analyses were performed on muscles from three carcasses per cell. A pH meter with a glass tip electrode was used to determine muscle pH. Water holding capacity was determined as expressible moisture and was measured as the percentage of moisture loss due to centrifugation. Total muscle collagen content was calculated from hydroxyproline, measured with a spectrophotometer. Total heme-iron was extracted using an acetone extraction procedure and quantified using a spectrophotometer. Proximate composition consisted of fat, moisture and ash determination and was measured by Soxhlet ether extraction (fat) and a LEC Thermogravimetric Analyzer (moisture and ash). Data were analyzed using the General Linear Model procedure of Statistical Analysis System (SAS). Comparisons between dairy and beef body types were not analyzed due to differences in carcass weight ranges.

Results

The results of this project are given in Tables 1-4. The most intriguing aspect of these data was the large variation present in all measured characteristics, found in all 21 muscles. Variation was seen within a given muscle, as well as among muscles for a given characteristic. Objective color was represented by three quantitative values, L*, a* and b*, representing lightness (0 = black to 100 = white), redness (-60 = green to +60 = red), and yellowness (-60 = blue to +60 = yellow), respectively. Muscle lightness ranged from 24.8 (*Rectus femoris*) to 38.3 (*Semitendinosis*) in beef and 33.1 (*Vastus medialis*) to 38.8 (*Semitendinosis*) in dairy. *Tensor fascia latae* exhibited the lowest mean redness values in both beef and dairy (26.9 and 27.9 respectively) muscles, while *Serratus ventralis* (29.8, beef and 30.6, dairy) measured the highest. Muscle yellowness ranged from 20.1 (*Tensor fascia latae*) to 23.2 (*Infraspinatus*) for beef and 20.4 to 24.1 for dairy represented by the same muscles, respectively.

Warner-Bratzler shear force has become an industry standard for measurement of cooked meat tenderness. Tenderness is a major factor influencing palatability of meat and a main determinant of consumer acceptance. The *Multifidus/Spinalis dorsi* (3.4 lb) had the lowest shear force measurement of the muscles from beef carcasses, while the *Psoas major* (3.1 lb) was the lowest of dairy muscles. The least tender (highest shear force measurement) muscle was the *Biceps femoris* for both beef and dairy (9.5 lb and 8.5 lb, respectively) muscles.

Moisture retention in meat products will have a significant effect on processing yield. Increased water holding capacity, measured as moisture loss

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Table 1. Properties of beef muscles.

Muscles	L* value		a* value		b* value		Warner-Bratzler shear force (lb)		Expressible moisture (%)	
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Adductor	34.9	(4.2)	29.7	(2.4)	22.9	(2.9)	4.5	(1.0)	47.0	(4.3)
Biceps femoris	34.8	(4.8)	29.2	(2.4)	22.7	(2.6)	9.5	(2.7)	44.2	(4.6)
Complexus	33.4	(3.3)	28.5	(2.3)	21.2	(3.0)	5.3	(1.4)	41.1	(4.9)
Deep pectoral	33.6	(4.8)	27.7	(2.5)	21.1	(2.6)	8.7	(2.6)	42.1	(5.8)
Gluteus medius	32.6	(3.7)	28.3	(2.3)	21.7	(2.6)	5.7	(1.5)	45.7	(4.1)
Infraspinatus	31.4	(4.4)	29.7	(2.1)	23.2	(4.5)	4.9	(1.1)	38.1	(4.2)
Latissimus dorsi	33.1	(4.2)	27.5	(2.9)	20.3	(3.5)	6.0	(1.5)	41.1	(6.1)
Longissimus dorsi	33.9	(4.3)	28.1	(2.5)	21.7	(2.6)	7.0	(1.5)	44.5	(3.6)
Multifidus/Spinalis dorsi	31.8	(3.7)	28.7	(3.1)	21.8	(3.7)	3.4	(1.2)	36.1	(6.7)
Psoas major	34.1	(3.6)	27.2	(3.0)	20.9	(2.9)	3.5	(0.6)	43.9	(3.5)
Rectus femoris	24.8	(4.0)	28.9	(2.8)	22.4	(3.0)	5.9	(1.6)	43.1	(5.3)
Semimembranosis	33.2	(4.7)	29.5	(2.3)	23.0	(2.7)	6.0	(1.3)	46.1	(4.7)
Semitendinosis	38.3	(4.6)	28.0	(2.2)	21.8	(1.9)	7.6	(1.5)	44.3	(4.6)
Serratus ventralis	33.4	(2.6)	29.8	(1.9)	23.1	(2.4)	5.3	(1.0)	39.9	(5.8)
Supraspinatus	34.2	(3.9)	28.9	(2.6)	21.9	(3.2)	4.5	(1.4)	41.8	(4.0)
Teres major	35.8	(3.3)	27.5	(2.6)	20.7	(2.9)	3.7	(0.8)	45.8	(5.2)
Tensor fascia latae	33.1	(4.5)	26.9	(2.6)	20.1	(2.8)	5.3	(1.3)	42.0	(5.5)
Triceps brachii	32.2	(4.4)	28.5	(2.5)	22.1	(2.8)	5.2	(1.0)	43.2	(5.0)
Vastus lateralis	33.3	(5.0)	28.0	(2.1)	21.3	(2.4)	5.8	(1.9)	45.0	(5.2)
Vastus medialis	32.5	(4.4)	27.4	(2.6)	20.6	(3.2)	3.8	(1.1)	43.9	(4.9)
Vastus intermedius	35.7	(4.3)	29.0	(2.7)	22.8	(3.1)	3.8	(0.8)	43.0	(4.1)

Table 2. Properties of beef muscles.

Muscles	pH		Total collagen (mg/g)		Heme-Iron (ppm)		Fat (%)		Moisture (%)		Ash (%)	
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d.)	Mean	(s.d.)
Adductor	5.6	(.22)	7.4	(3.4)	35.5	(10.6)	3.5	(1.7)	75.1	(1.4)	1.6	(.26)
Biceps femoris	5.7	(.20)	10.9	(4.7)	32.5	(10.4)	4.3	(1.9)	75.0	(1.7)	1.6	(.28)
Complexus	5.9	(.21)	10.9	(3.3)	34.9	(7.2)	4.0	(2.0)	76.0	(1.9)	1.3	(.25)
Deep pectoral	5.7	(.22)	10.3	(4.0)	30.1	(8.3)	3.4	(1.8)	76.4	(1.6)	1.5	(.37)
Gluteus medius	5.7	(.17)	9.2	(5.6)	34.5	(9.5)	4.7	(1.8)	74.4	(1.7)	1.6	(.29)
Infraspinatus	6.1	(.18)	9.4	(6.2)	35.0	(6.2)	5.6	(2.7)	74.3	(2.2)	1.2	(.33)
Latissimus dorsi	5.9	(.27)	18.3	(2.2)	30.6	(8.3)	3.0	(1.6)	76.4	(1.4)	1.5	(.25)
Longissimus dorsi	5.6	(.19)	9.4	(3.1)	31.0	(8.9)	4.4	(2.2)	74.4	(2.1)	1.5	(.27)
Mutifidus/Spinalis dorsi	3.1	(.18)	6.3	(3.5)	37.1	(8.2)	7.5	(2.8)	76.1	(2.6)	1.2	(.27)
Psoas major	5.7	(.26)	13.3	(2.4)	31.6	(9.0)	5.7	(2.3)	74.5	(2.2)	1.6	(.24)
Rectus femoris	5.9	(.26)	4.7	(3.3)	31.2	(9.5)	3.1	(1.2)	76.1	(1.1)	1.4	(.28)
Semimembranosis	5.6	(.23)	7.8	(2.6)	32.9	(9.0)	3.4	(1.5)	75.3	(1.4)	1.5	(.33)
Semitendinosis	5.7	(.25)	6.8	(3.7)	25.2	(8.7)	2.8	(1.3)	76.1	(1.3)	1.4	(.25)
Serratus ventralis	6.0	(.21)	8.2	(2.6)	35.4	(7.7)	5.0	(2.8)	75.1	(2.4)	1.3	(.33)
Supraspinatus	6.0	(.23)	10.0	(3.6)	34.0	(7.4)	3.6	(1.6)	74.5	(1.3)	1.5	(.28)
Teres major	5.9	(.26)	8.8	(6.3)	28.9	(8.9)	3.0	(1.4)	76.7	(1.6)	1.5	(.35)
Tensor fascia latae	5.8	(.25)	7.9	(2.9)	29.1	(8.9)	3.6	(2.0)	75.7	(2.1)	1.4	(.27)
Triceps brachii	5.8	(.25)	10.5	(5.1)	36.4	(10.6)	3.5	(1.6)	75.7	(1.4)	1.5	(.29)
Vastus lateralis	5.8	(.24)	6.1	(2.7)	34.3	(8.6)	2.6	(1.2)	76.2	(1.1)	1.5	(.23)
Vastus medialis	5.9	(.27)	6.7	(4.6)	34.9	(8.4)	2.6	(1.2)	77.3	(1.0)	1.4	(.22)
Vastus intermedius	6.3	(.27)	8.9	(4.5)	36.7	(8.7)	4.7	(1.9)	76.2	(1.2)	1.4	(.28)

due to centrifugation, will decrease cooking loss and improve consumer satisfaction. *Multifidus/Spinalis dorsi* exhibited the lowest percentage weight loss due to centrifugation, 36.1% and 39.3%, for both beef and dairy muscles, respectively. *Adductor* (47.0%) muscles from beef carcasses and *Semimembranosis* (46.8%) muscles from dairy carcasses produced the largest percentage weight loss due to centrifugation of the 21 muscles (lowest water holding capacity).

Muscle pH has a large effect on muscle color, protein functionality and water-holding capacity. All of these factors play important roles in the stability and acceptability of meat products. Higher pH indicates improved water holding capacity, as well as darker color, with the side effect of shorter shelf life. Muscle pH ranged from 5.6 (*Longissimus dorsi, Adductor,* and *Semimembranosis*) to 6.3 (*Vastus intermedius*) for both beef and dairy muscles.

Muscle total collagen content is an indicator of connective tissue found in a meat sample. Connective tissue has been shown to affect the tenderness and palatability of meat. Of the 21 beef muscles, the *Psoas major* (4.7 mg/g) exhibited the lowest total collagen content while the *Vastus medialis* (6.4 mg/g) was lowest of dairy muscles. The *Infraspinatus* muscle was found to have the highest mean total collagen content for both beef and dairy (18.3 mg/g and 22.9mg/g, respectively) muscles.

Heme-iron content is a measure of

Table 3. Properties of dairy muscles.

	L* value		a* value		b* value		Warner-Bratzler shear force (lb)		Expressible moisture (%)	
Muscles	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d)
Adductor	35.2	(3.2)	30.4	(2.5)	23.0	(3.2)	4.3	(0.8)	46.3	(3.4)
Biceps femoris	35.9	(3.4)	29.4	(2.0)	22.4	(2.2)	8.5	(1.7)	43.4	(4.6)
Complexus	35.1	(2.5)	29.8	(1.6)	22.7	(2.2)	4.5	(1.3)	42.7	(4.0)
Deep pectoral	35.7	(2.5)	28.9	(2.0)	22.1	(2.5)	7.8	(4.1)	42.7	(4.8)
Gluteus medius	33.3	(2.3)	28.9	(2.4)	22.0	(2.7)	5.6	(1.4)	45.7	(4.3)
Infraspinatus	35.2	(2.1)	30.6	(1.3)	24.1	(2.1)	4.8	(1.2)	41.4	(3.4)
Latissimus dorsi	33.5	(2.2)	28.3	(1.9)	20.9	(2.8)	5.4	(1.6)	42.1	(4.7)
Longissimus dorsi	35.0	(3.6)	29.7	(2.3)	23.1	(2.8)	5.4	(1.4)	44.3	(4.0)
Multifidus/Spinalis dorsi	33.5	(3.3)	29.5	(3.0)	22.5	(3.5)	3.9	(1.5)	39.3	(5.9)
Psoas major	36.6	(2.3)	28.0	(2.5)	21.1	(2.6)	3.1	(0.6)	44.9	(3.7)
Rectus femoris	35.6	(2.6)	29.8	(2.0)	22.8	(2.2)	4.8	(1.2)	43.7	(4.2)
Semimembranosis	33.3	(2.0)	28.8	(2.6)	21.7	(2.9)	5.3	(0.9)	46.8	(4.0)
Semitendinosis	38.8	(3.3)	29.0	(2.5)	22.5	(2.3)	6.7	(1.2)	45.6	(3.9)
Serratus ventralis	34.4	(2.5)	30.6	(2.0)	24.0	(2.7)	4.4	(0.9)	41.9	(4.2)
Supraspinatus	33.8	(2.9)	29.1	(2.4)	21.9	(3.2)	4.7	(1.1)	43.1	(4.4)
Teres major	36.2	(3.2)	29.1	(2.7)	22.1	(3.2)	4.0	(0.6)	46.7	(4.7)
Tensor fascia latae	34.3	(3.5)	27.9	(1.9)	20.4	(2.0)	4.7	(1.1)	40.9	(5.1)
Triceps brachii	33.3	(2.3)	29.8	(2.2)	23.3	(3.3)	4.8	(0.7)	44.3	(3.2)
Vastus lateralis	34.1	(2.7)	29.1	(2.5)	22.2	(2.8)	6.2	(1.6)	45.5	(4.2)
Vastus medialis	33.1	(2.8)	28.3	(1.8)	21.6	(2.1)	4.4	(1.1)	43.2	(4.4)
Vastus intermedius	34.9	(3.6)	29.3	(1.3)	22.2	(1.5)	4.3	(0.9)	43.9	(5.5)

Table 4. Properties of dairy muscles.

	pH		Total collagen (mg/g)		Heme-Iron (ppm)		Fat (%)		Moisture (%)		Ash (%)	
Muscles	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d)	Mean	(s.d.)	Mean	(s.d.)
Adductor	5.6	(.17)	6.7	(2.0)	36.7	(10.2)	3.8	(1.6)	74.2	(1.2)	1.5	(.30)
Biceps femoris	5.7	(.17)	12.4	(4.4)	33.2	(8.1)	5.4	(2.3)	73.6	(1.9)	1.5	(.34)
Complexus	5.9	(.14)	11.2	(2.1)	36.7	(8.7)	6.1	(3.1)	73.4	(2.6)	1.3	(.28)
Deep pectoral	5.7	(.14)	10.3	(2.2)	31.0	(9.6)	4.4	(1.7)	74.7	(1.7)	1.5	(.35)
Gluteus medius	5.7	(.14)	12.1	(4.8)	35.3	(7.5)	5.8	(2.0)	72.9	(1.5)	1.5	(.32)
Infraspinatus	6.0	(.15)	22.9	(5.7)	38.8	(9.4)	6.6	(2.8)	73.0	(2.3)	1.3	(.27)
Latissimus dorsi	5.8	(.20)	8.6	(2.1)	30.7	(9.6)	3.4	(1.5)	75.6	(1.4)	1.4	(.34)
Longissimus dorsi	5.6	(.15)	6.7	(2.8)	31.4	(8.4)	6.3	(2.7)	72.0	(2.1)	1.4	(.34)
Mutifidus/Spinalis dorsi	6.0	(.17)	15.9	(2.9)	39.0	(9.6)	9.9	(3.6)	70.8	(3.1)	1.2	(.30)
Psoas major	5.8	(.24)	7.2	(4.3)	32.8	(8.1)	7.4	(2.6)	72.4	(2.5)	1.5	(.32)
Rectus femoris	5.9	(.24)	7.9	(1.9)	33.5	(9.4)	3.7	(2.0)	74.8	(1.5)	1.4	(.29)
Semimembranosis	5.6	(.15)	7.1	(2.9)	33.2	(10.4)	4.3	(1.6)	73.9	(1.4)	1.5	(.34)
Semitendinosis	5.7	(.19)	9.3	(3.0)	29.6	(10.0)	3.3	(1.8)	75.0	(1.5)	1.3	(.28)
Serratus ventralis	6.0	(.18)	8.8	(3.9)	36.5	(6.7)	8.4	(3.9)	71.7	(3.1)	1.3	(.32)
Supraspinatus	6.0	(.19)	10.7	(3.8)	34.5	(7.4)	3.6	(1.7)	75.7	(1.3)	1.4	(.39)
Teres major	5.9	(.24)	9.1	(3.6)	33.3	(10.9)	3.9	(1.6)	75.2	(1.4)	1.4	(.41)
Tensor fascia latae	5.8	(.27)	8.0	(1.6)	31.7	(9.3)	6.8	(3.5)	72.9	(3.1)	1.3	(.31)
Triceps brachii	5.8	(.17)	10.1	(2.6)	37.0	(10.4)	4.4	(2.1)	74.5	(1.5)	1.5	(.30)
Vastus lateralis	5.8	(.23)	7.2	(2.1)	34.7	(8.4)	3.2	(1.4)	75.2	(0.9)	1.5	(.30)
Vastus medialis	5.9	(.26)	6.4	(2.6)	38.5	(9.0)	2.7	(1.3)	76.6	(1.1)	1.4	(.26)
Vastus intermedius	6.3	(.27)	9.6	(3.3)	37.1	(7.9)	5.0	(1.8)	75.2	(1.7)	1.3	(.27)

the total pigment in a muscle sample. Heme-iron has an influence on the visual appearance (color) of meat and therefore on its acceptability by consumers. Heme-iron ranged from 25.2 ppm (*Semitendinosis*) for beef muscles and 29.6 ppm (*Semitendinosis*) for dairy muscles to 37.1 ppm (*Multifidus/Spinalis dorsi*) for beef and 39.0 ppm (*Multifidus/Spinalis dorsi*) for dairy muscles.

Proximate composition is an analysis to determine fat, moisture and ash. The *Vastus lateralis* (2.6%) and *Vastus medialis* (2.7%) had the low mean for fat in both beef and dairy muscles, respectively. The *Multifidus/Spinalis dorsi* from both beef (7.5%) and dairy (9.9%) carcasses exhibited the highest percentage fat. Percentage moisture ranged from 74.3% (*Infraspinatus*) to 77.3% (*Vastus medialis*) for beef muscles and 70.8% (*Multifidus/Spinalis dorsi*) to 76.6% (*Vastus medialis*) for dairy muscles. Percentage ash ranged from 1.2% (*Multifidus/Spinalis dorsi*) for both beef and dairy muscles to 1.6% (*Psoas major* and 3 other muscles) for beef muscles and 1.5% (*Psoas major* and 7 other muscles) for dairy muscles.

The effects of the carcass selection criteria (12th rib fat thickness, carcass weight, skeletal maturity and muscling level) were evaluated for significance. Muscle color (L*, a*, and b*) was rarely influenced by carcass selection criteria in beef and dairy (< 5 of 21 muscles, depending on the criteria) muscles. Most selection criteria had low relationships

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to tenderness in beef (1 or 2 muscles, depending on selection criteria) and dairy (< 5 of 21 muscles, depending on selection criteria). Muscle pH was influenced by fat thickness and carcass muscling in beef (9 and 10 muscles, respectively) muscles, while few dairy (1 or 2 depending on criteria) muscles exhibited a relationship with any selection criteria. All selection criteria had low relationships to expressible moisture in beef and dairy (< 5 of 21 muscles) muscles. Total collagen was most frequently affected by maturity in beef (4 of 21 muscles), while weight had the greatest influence on dairy (6 of 21 muscles) muscles. Fat thickness most often influenced total heme-iron content in beef (12 of 21 muscles) muscles, while all selection criteria had little effect on dairy (< 5 of 21 muscles) muscles. Carcass fatness was the most common carcass selection trait related to muscle fat (16 beef and 14 dairy muscles) and moisture (21 beef and 19 dairy muscles) content. Muscle ash content was seldom influenced by any selection criteria for beef and dairy (< 5 of 21 muscles depending on criteria) muscles.

This research was performed as a follow-up to the muscle profile research of chuck and round muscles from fed cattle (*2001 Nebraska Beef Report,* pp 99-103). Muscles from cow carcasses exhibited a larger expressible moisture value than did muscles from the fed cattle study, probably because of differences in methodologies. In this study ground samples were collected while in the previous study a whole muscle cube was used. Values for pH and Warner-Bratzler shear force were higher in cow muscles as compared with the previous study. Muscles from cow carcasses were shown to have lower L* and a* values indicating cow muscles were darker and less red than those from fed cattle. As expected, the cow muscles were leaner than those of fed cattle, indicated by lower percentage fat. Variation in trait values were detected in both studies. As a general rule cow muscles exhibited higher variability than muscles from fed cattle for the majority of traits measured.

These data indicate a vast range of values of measured characteristics for both beef and dairy cow muscles. Of the four selection criteria, estimated 12th rib fat thickness influenced the most muscle characteristics, particularly percentage fat and moisture. However, in general there was a lack of significant effects by the carcass characteristics on muscle characteristics measured. This variation indicates muscles exist that can be better utilized as value added products to increase the value of cow carcasses.

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