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Physical and Chemical Properties of 39 Muscles from the Beef Chuck and Round

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Variation among the muscles of the beef chuck and round are profound. Physical and chemical properties of these muscles were shown to be affected the most by quality grade.

Summary

Twenty-seven and 12 muscles, respectively, from the chuck and round were analyzed for objective color, expressible moisture, emulsion capacity, pH, total collagen content total heme-iron content, and proximate composition. Observations of these physical and chemical properties showed a vast range of results. The range in data reveal the variation within and among muscles. Knowledge of this variation can lead to proper usage, thereby increasing value of the beef chuck and round. Quality grade had the most pronounced effects, whereas yield grade and weight showed fewer effects on these traits across all 39 muscles.

Introduction

With the increasing popularity of value-added products and the decline in value of the beef chuck and round (20 - 25% over a five-year period), it's necessary to characterize the muscles from these two primals. Muscle has unique physical and chemical properties, which when known and understood can allow for development of value-added products. Information (physical and chemical properties) of many muscles within the chuck and round was lacking until this study was undertaken. It is also important to describe the effects of quality grade, yield grade, and weight of carcass on these properties. Therefore, the objectives of this study were to determine the physical and chemical properties of 39 muscles from the beef chuck and round and the effects of quality grade, yield grade, and weight on these properties.

Procedure

Ninety-four chucks and 94 rounds were selected at the IBP Inc., Dakota City, Neb. plant based on quality grade (upper 2/3 Choice, low Choice, and Select), yield grade (1, 2, 3, and 4 and 5 together), and carcass weight (550 - 650 lb and 850 - 950 lb). Twenty-seven and 12 muscles, respectively, were dissected from chucks and rounds. Each individual muscle was then trimmed of all external fat and connective tissue. Objective color (L*, a*, and b* values) was observed using a Hunter Lab Mini Scan device with a 1- inch port. Expressible moisture, a method of measuring water holding capacity, was measured as the percentage of moisture lost due to centrifugation. Muscle pH was determined using a pH meter with a spear tip combination electrode. Emulsion capacity, which determines the amount of oil a specific muscle/protein system can bind, was expressed as mL oil bound/2.5g of lean tissue. Total collagen measures the amount of connective tissue within a given muscle. It was quantified by measuring the total content of hydroxyproline in a sample, which is related to collagen. Total collagen was expressed as mg of collagen/g of lean tissue. Total heme-iron measures the amount of myoglobin and hemoglobin within a given muscle. Acetone and hydrochloric acid were used to separate myoglobin and hemoglobin from the sample. This solution then was read using a spectrophotometer; results were expressed in parts per million (ppm). Proximate composition (fat, moisture and ash) was determined using Soxhlet ether extraction procedures and a LECO Thermogravimetric Analyzer (a continuous weighing and heating device). Fat, moisture and ash were expressed as mg/g (%) of lean tissue. Data were analyzed statistically using mixed and least square means procedures.

Results

Across all 39 muscles, variation was evident in all analyzed physical and chemical properties (Tables 1 - 4). Objective color (L*, a*, and b*) values represent a color scale. The higher the L* (ranging from 0 = black to 100 = white), the lighter the muscle. As a* (ranging from negative 60 = green to positive 60 = red) increases, the muscle becomes more red. As b* (ranging from negative 60 = blue to positive 60 = yellow) increases, the muscle becomes more yellow. The overall means and standard deviations observed for L*, a*, and b* were 41.06 $\pm$ 4.55, 29.57 $\pm$ 4.05, and 22.78 $\pm$ 4.32, respectively. The measurement of objective color can be correlated to other chemical properties such as pH and total heme-iron, which together can be related to the shelf-life of a specific muscle and the ultimate color of a processed product.

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Table 1. Properties of chuck muscles.

Muscle	Emulsion capacity (mL oil/2.5g)		Expressible Moisture (%)		L* - value		a* - value		b* - value	
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)
Biceps brachii	169.71	(14.7)	37.52	(4.22)	38.56	(3.56)	28.65	(3.75)	21.85	(4.32)
Brachiocephalicus omo-transversarius	172.13	(18.1)	37.57	(5.95)	42.66	(2.70)	28.79	(3.27)	21.61	(3.34)
Brachialis	176.61	(20.6)	37.62	(5.41)	38.87	(4.03)	28.08	(3.74)	20.41	(4.28)
Cutaneous omo-brachialis	179.37	(27.3)	34.85	(8.17)	52.08	(5.63)	19.51	(4.54)	14.68	(4.45)
Complexus	175.10	(17.1)	36.34	(5.31)	40.58	(2.47)	31.10	(3.00)	23.69	(3.56)
Deltoideus	173.07	(15.1)	38.56	(4.62)	43.80	(3.68)	27.47	(3.33)	20.71	(3.39)
Deep pectoral	175.53	(20.6)	37.46	(4.57)	41.31	(3.08)	29.79	(3.23)	22.56	(3.52)
Dorsalis oblique	175.04	(19.3)	37.59	(4.52)	43.35	(2.64)	30.09	(3.34)	22.79	(3.72)
Infraspinatus	171.45	(15.0)	37.63	(4.70)	38.85	(2.60)	31.25	(3.08)	24.82	(3.64)
Intertransversales	174.26	(14.9)	35.84	(5.24)	39.30	(4.04)	29.98	(3.17)	22.82	(3.71)
Latissimus dorsi	175.02	(19.6)	37.82	(5.15)	41.51	(3.50)	29.07	(4.03)	22.05	(4.35)
Longissimus capitus et Atlantis	175.15	(14.9)	37.19	(5.31)	39.71	(3.83)	29.90	(4.17)	22.63	(4.57)
Longissimus costarum	174.15	(18.3)	34.85	(5.90)	40.01	(4.31)	27.08	(3.77)	19.90	(3.84)
Longissimus dorsi	173.70	(16.8)	37.76	(4.27)	40.55	(3.03)	31.13	(3.46)	23.98	(4.00)
Levatores costarum	174.86	(19.7)	36.94	(5.28)	39.33	(3.87)	29.14	(3.62)	22.34	(3.88)
Multifidus/Spinalis dorsi	168.49	(17.0)	36.38	(5.47)	38.08	(3.34)	30.60	(3.87)	23.20	(4.94)
Rhomboideus	173.67	(16.2)	36.42	(4.77)	41.35	(3.04)	28.43	(3.48)	20.99	(3.90)
Scalenus dorsalis	170.82	(19.7)	37.51	(4.73)	44.61	(3.67)	29.55	(3.72)	21.74	(3.92)
Serratus ventralis	177.25	(16.4)	37.20	(5.72)	39.64	(2.98)	31.42	(2.87)	24.61	(3.49)
Splenius	179.35	(19.6)	36.34	(6.53)	40.49	(2.88)	29.40	(3.78)	21.98	(4.19)
Superficial pectoral	172.12	(15.9)	35.92	(5.52)	44.09	(3.75)	28.10	(3.06)	20.78	(3.07)
Subscapularis	173.06	(14.4)	37.85	(4.64)	38.65	(4.09)	30.30	(2.86)	23.45	(3.46)
Supraspinatus	178.80	(17.9)	38.73	(4.95)	40.82	(3.35)	30.92	(3.03)	23.83	(3.51)
Teres major	178.89	(24.1)	37.12	(4.83)	41.48	(3.75)	29.98	(3.74)	23.02	(4.21)
Tensor fascia antibrachii	173.10	(17.8)	37.92	(4.73)	42.47	(3.17)	28.03	(3.86)	20.40	(4.11)
Trapezius	175.24	(25.0)	35.64	(5.07)	44.89	(4.69)	25.65	(4.64)	18.44	(5.41)
Triceps brachii	169.64	(19.7)	36.41	(20.20)	39.47	(2.80)	31.50	(3.62)	24.78	(4.38)

Table 2. Properties of chuck muscles.

Muscle	Total Collagen (mg/g)		Heme – Iron (ppm)		pH		Fat (mg/g)		Moisture (mg/g)		Ash (mg/g)	
	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)
Biceps brachii	13.14	(7.32)	24.70	(2.88)	5.79	(0.33)	6.79	(2.17)	72.74	(1.66)	1.07	(0.19)
Brachiocephalicus omo-transversarius	11.28	(6.48)	16.86	(3.12)	5.75	(0.31)	6.40	(2.14)	73.10	(1.47)	1.14	(0.18)
Brachialis	11.81	(4.36)	23.84	(2.85)	5.76	(0.30)	4.04	(1.23)	75.41	(1.19)	1.43	(0.22)
Cutaneous omo-brachialis	10.72	(5.68)	15.20	(6.47)	5.81	(0.32)	14.03	(4.19)	64.88	(6.70)	1.04	(0.19)
Complexus	12.59	(4.68)	22.14	(2.13)	5.76	(0.33)	8.37	(1.88)	72.02	(1.48)	1.48	(0.08)
Deltoideus	13.57	(8.13)	16.72	(2.09)	5.77	(0.33)	6.45	(1.75)	73.32	(1.71)	1.23	(0.17)
Deep pectoral	10.56	(4.67)	19.90	(3.25)	5.73	(0.32)	5.49	(1.93)	72.66	(1.32)	1.41	(0.23)
Dorsalis oblique	10.13	(3.84)	18.35	(2.18)	5.88	(0.37)	9.07	(2.32)	71.91	(1.89)	1.12	(0.18)
Infraspinatus	8.72	(3.33)	23.55	(2.87)	5.78	(0.32)	9.18	(2.54)	70.81	(2.05)	1.08	(0.11)
Intertransversales	13.82	(5.55)	23.39	(2.92)	5.77	(0.34)	8.56	(2.45)	71.86	(1.96)	1.03	(0.14)
Latissimus dorsi	12.53	(7.67)	18.37	(2.94)	5.74	(0.32)	5.99	(1.51)	72.34	(1.41)	1.23	(0.16)
Longissimus capitus et Atlantis	11.87	(7.62)	21.44	(3.83)	5.79	(0.32)	6.49	(1.92)	73.23	(1.37)	1.07	(0.12)
Longissimus costarum	13.39	(8.19)	23.00	(3.40)	5.86	(0.33)	10.06	(3.48)	69.65	(2.75)	1.08	(0.20)
Longissimus dorsi	14.49	(9.07)	22.02	(4.48)	5.71	(0.27)	7.74	(1.95)	70.52	(1.58)	1.20	(0.14)
Levatores costarum	8.87	(4.40)	21.77	(1.96)	5.86	(0.32)	9.86	(2.45)	70.39	(1.95)	1.09	(0.17)
Multifidus/Spinalis dorsi	16.20	(11.71)	24.93	(2.45)	5.80	(0.41)	14.22	(2.67)	68.04	(2.11)	1.01	(0.21)
Rhomboideus	12.27	(5.09)	20.69	(3.45)	5.82	(0.32)	6.35	(1.93)	72.08	(1.43)	1.38	(0.15)
Scalenus dorsalis	10.06	(4.26)	15.75	(1.99)	5.75	(0.34)	9.11	(3.11)	71.22	(2.53)	0.98	(0.18)
Serratus ventralis	8.78	(3.82)	24.33	(3.13)	5.81	(0.28)	12.21	(3.05)	68.77	(2.43)	1.02	(0.11)
Splenius	11.16	(9.16)	19.37	(3.18)	5.71	(0.29)	4.35	(1.44)	74.43	(1.39)	1.33	(0.24)
Superficial pectoral	8.21	(4.90)	20.15	(4.97)	5.77	(0.27)	10.66	(2.90)	69.79	(2.29)	1.10	(0.09)
Subscapularis	10.64	(6.11)	20.55	(2.39)	5.85	(0.33)	4.60	(1.26)	73.21	(1.19)	1.31	(0.20)
Supraspinatus	17.77	(11.00)	21.47	(3.25)	5.82	(0.32)	4.95	(1.08)	74.29	(0.95)	1.37	(0.15)
Teres major	11.33	(3.74)	19.94	(2.33)	5.72	(0.34)	5.25	(1.29)	73.54	(1.11)	1.23	(0.31)
Tensor fascia antibrachii	9.95	(5.36)	14.74	(2.91)	5.79	(0.37)	4.57	(1.36)	74.08	(1.16)	1.24	(0.15)
Trapezius	8.85	(4.90)	16.03	(3.19)	5.82	(0.33)	8.65	(1.91)	71.62	(2.06)	0.93	(0.11)
Triceps brachii	9.97	(3.84)	21.53	(2.43)	5.78	(0.38)	5.65	(1.55)	73.23	(1.27)	1.44	(0.17)

Table 3. Properties of round muscles.

	Emulsion capacity (mL oil/2.5g)		Expressible Moisture (%)		L* - value		a* - value		b* - value	
Muscles	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)
Adductor	172.73	(17.9)	38.89	(4.41)	42.32	(4.08)	31.09	(3.71)	25.47	(3.00)
Biceps femoris	171.33	(16.5)	38.27	(6.09)	41.38	(2.78)	32.14	(2.61)	26.55	(2.62)
Gluteus medius	176.76	(21.2)	37.78	(4.72)	44.53	(3.55)	27.74	(4.42)	22.47	(3.14)
Gracilis	175.33	(18.8)	38.52	(4.99)	36.15	(2.92)	30.89	(3.05)	23.48	(3.54)
Pectineus	175.51	(18.8)	38.24	(5.20)	42.10	(4.54)	31.96	(2.14)	25.44	(2.51)
Rectus femoris	174.12	(19.5)	38.12	(4.89)	41.08	(3.01)	30.29	(3.32)	25.16	(2.38)
Sartorius	171.75	(20.0)	39.33	(4.66)	40.79	(3.07)	29.10	(3.13)	21.39	(3.15)
Semimembranosus	178.62	(23.7)	38.68	(4.48)	39.44	(2.96)	32.56	(2.53)	27.00	(2.57)
Semitendinosus	175.29	(17.1)	37.87	(4.11)	44.39	(3.11)	30.06	(2.23)	24.27	(2.11)
Vastus intermedius	173.25	(20.4)	37.84	(5.09)	35.22	(2.99)	30.16	(1.81)	23.32	(2.27)
Vastus lateralis	172.84	(16.1)	39.06	(4.24)	39.45	(2.75)	31.95	(2.35)	25.65	(2.70)
Vastus medialis	169.19	(12.8)	38.50	(4.23)	35.38	(3.53)	31.03	(2.65)	24.26	(3.51)

Table 4. Properties of round muscles.

	Total Collagen (mg/g)		Heme – Iron (ppm)		pH		Fat (mg/g)		Moisture (mg/g)		Ash (mg/g)	
Muscles	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)	Mean	(s.d.)
Adductor	12.31	(11.89)	22.57	(2.70)	5.76	(0.30)	4.57	(1.21)	72.86	(0.87)	1.49	(0.23)
Biceps femoris	12.36	(8.32)	22.43	(3.48)	1.69	(0.30)	6.86	(1.65)	71.61	(1.29)	1.29	(0.17)
Gluteus medius	11.80	(5.77)	19.76	(2.57)	5.76	(0.34)	5.94	(1.69)	71.44	(1.51)	1.40	(0.16)
Gracilis	15.20	(7.92)	24.31	(4.22)	5.76	(0.31)	3.93	(1.24)	74.78	(1.06)	1.51	(0.17)
Pectineus	12.97	(6.71)	21.28	(2.64)	5.84	(0.30)	3.16	(0.83)	74.45	(0.83)	1.56	(0.18)
Rectus femoris	11.06	(4.23)	19.60	(3.10)	5.72	(0.32)	5.11	(1.79)	73.33	(1.22)	1.50	(0.17)
Sartorius	10.49	(3.39)	19.40	(2.87)	5.75	(0.30)	3.14	(1.29)	74.69	(1.11)	1.54	(0.27)
Semimembranosus	10.40	(4.91)	21.22	(3.29)	5.74	(0.31)	4.36	(1.24)	72.79	(0.78)	1.75	(0.26)
Semitendinosus	11.56	(6.20)	14.65	(2.16)	5.72	(0.30)	4.08	(0.90)	73.27	(0.77)	1.53	(0.15)
Vastus intermedius	9.89	(3.46)	27.27	(2.92)	5.87	(0.40)	8.43	(2.56)	72.91	(1.77)	0.98	(0.11)
Vastus lateralis	12.71	(5.39)	20.29	(3.18)	5.77	(0.30)	4.44	(1.15)	73.54	(0.97)	1.53	(0.26)
Vastus medialis	14.92	(8.75)	25.45	(3.58)	5.78	(0.28)	4.35	(1.27)	75.02	(1.14)	1.47	(0.33)

The mean and standard deviation for expressible moisture was observed to be 37.50 ± 5.15%. Expressible moisture (along with pH) can reveal a good understanding of protein functionality. Knowledge of the amount of moisture lost due to centrifugation allows product developers to use technologies to minimize the loss of moisture (loss of yield and palatability).

The mean and standard deviation of pH was observed to be 5.78 ± 0.32. Muscle pH as previously mentioned reveals a better understanding of protein functionality. As muscle pH increases, expressible moisture decreases. However, higher pH meat appears to be darker in color (lower L* values) and also tends to have a shorter shelf-life.

The mean and standard deviation for emulsion capacity were observed to be 174.2 ± 18.8 mL oil bound/2.5 g of lean tissue. This property of muscle can also characterize a specific muscle, as higher amounts of oil bound in a protein system can be related to the amount of salt-soluble protein (major binding protein) within that system. Such information can allow for increased yield and therefore increased profit in the production of sausage-type products.

The mean and standard deviation of total collagen was 11.69 ± 6.54 mg/g of lean tissue. This property of muscle can be related to the tenderness and texture of meat.

The mean and standard deviation for total heme-iron was 20.78 ± 4.43 ppm. Total heme-iron can reveal information about a muscle's physical appearance (appearance to the eye), which is a major factor in consumer acceptance. The concentration of these color pigments is also an important determinant of processed meat color.

Fat, moisture and ash had mean percentages and standard deviations of 6.86 ± 3.45, 72.28 ± 2.83, and 1.26 ± 0.28, respectively.

To envision the variation between these 39 muscles, each muscle was categorized for each trait into three groups — desirable (white), intermediate (gray), or undesirable (black). These charts (Tables 5 and 6) show specific physical and chemical properties (fat, pH, expressible moisture, emulsion capacity, total heme-iron, and total collagen) which provide a quick, overall picture of a particular muscles' characteristics. This can be useful in selection of candidate muscles for value-added products.

Through investigation of the effects of quality grade, yield grade and weight on the physical and chemical properties, quality grade was the effect that was most frequently significant ($P < .05$). Across all physical and chemical properties, 2 to 31, 1 to 9, and 0 to 8 muscles out of 39 showed an effect due to quality grade, yield grade, and weight, respectively. For muscles with a significant quality grade effect, moisture (19 of 23 muscles) and ash (6 of 15 muscles) decreased while fat (26 of 31 muscles) and pH (7 of 16 muscles) increased with an increase in quality grade. It was also observed that properties showing an increase with an increase in quality grade were fat (26 out of 31 muscles) and pH (7 out of 16 muscles).

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Table 5. Classification of beef chuck muscles by trait.

	Fat	pH	Expressible Moisture	Emulsion Capacity	Heme-Iron	Total Collagen
Biceps brachii	light gray	light gray	light gray	dark gray	light gray	light gray
Brachiocephalicus omot.	light gray	light gray	light gray	light gray	light gray	light gray
Brachialis	white	light gray	light gray	white	light gray	light gray
Cutaneous omo brachialis	dark gray	light gray	white	white	dark gray	light gray
Complexus	light gray	light gray	light gray	white	light gray	light gray
Deep pectoral	light gray	light gray	light gray	white	dark gray	light gray
Deltoideus	light gray	light gray	dark gray	light gray	dark gray	light gray
Dorsalis oblique	light gray	white	light gray	white	dark gray	light gray
Infraspinatus	light gray	light gray	light gray	light gray	light gray	white
Intertransversales	light gray	light gray	white	light gray	light gray	light gray
Latissimus dorsi	light gray	light gray	light gray	white	dark gray	light gray
Longissimus cap. et Atlantis	light gray	light gray	light gray	white	light gray	light gray
Longissimus costarum	dark gray	white	white	light gray	light gray	light gray
Longissimus dorsi	light gray	light gray	light gray	light gray	light gray	light gray
Levatores costarum	light gray	white	light gray	light gray	light gray	white
Multifidus and spinalis dorsi	dark gray	white	light gray	dark gray	light gray	dark gray
Rhomboideus	light gray	white	light gray	light gray	light gray	light gray
Scalenus dorsalis	light gray	light gray	light gray	light gray	dark gray	light gray
Serratus ventralis	dark gray	white	light gray	white	light gray	white
Splenius	white	light gray	light gray	white	dark gray	light gray
Superficial pectoral	dark gray	light gray	white	light gray	light gray	white
Subscapularis	white	white	light gray	light gray	light gray	light gray
Supraspinatus	white	white	dark gray	white	light gray	dark gray
Tensor fascia antibroachii	white	light gray	light gray	light gray	dark gray	white
Teres major	light gray	light gray	light gray	light gray	dark gray	light gray
Trapezius	light gray	white	white	white	dark gray	white
Triceps brachii	light gray	light gray	light gray	dark gray	light gray	white

The white cells represent fat <5%, pH >5.8, WHC (expressible moisture) <36%, bind >175 mL, heme-iron >25 ppm, collagen <01 mg/g, while the dark gray cellsrepresent fat >10%, pH <5.7, WHC >38%, bind <170 mL, heme-iron <20 ppm, collagen >15 mg/g. The values represented by the light gray cells are intermediate.

Table 6. Classification of beef round muscles by trait.

	Fat	pH	Expressible Moisture	Emulsion Capacity	Heme-Iron	Total Collagen
Adductor	white	light gray	dark gray	light gray	light gray	light gray
Biceps femoris	light gray	dark gray	dark gray	light gray	light gray	light gray
Gluteus medius	light gray	light gray	light gray	white	dark gray	light gray
Gracilis	white	light gray	dark gray	white	light gray	dark gray
Pectineus	white	white	dark gray	white	light gray	light gray
Rectus femoris	light gray	light gray	dark gray	light gray	dark gray	light gray
Sartorious	white	light gray	dark gray	light gray	dark gray	light gray
Semimembranosus	white	light gray	dark gray	white	light gray	light gray
Semitendinosus	white	light gray	light gray	white	dark gray	light gray
Vastus intermedius	light gray	white	light gray	light gray	white	white
Vastus lateralis	white	light gray	dark gray	light gray	light gray	light gray
Vastus medialis	white	light gray	dark gray	light gray	white	light gray

The white cells represent fat <5%, pH >5.8, WHC (expressible moisture) <36%, bind >175 mL, heme-iron >25 ppm, collagen <01 mg/g, while the dark gray cellsrepresent fat >10%, pH <5.7, WHC >38%, bind <170 mL, heme-iron <20 ppm, collagen >15 mg/g. The values represented by the light gray cells are intermediate.

Significant ($P < .05$) yield grade effects were seldom linear, reflecting inconsistent trends as yield grade increased or decreased.

Moisture (4 out of 5 muscles), L* value (7 out of 7 muscles), a* value (8 out of 8 muscles), b* value (6 out of 6 muscles), and expressible moisture (5 out of 6 muscles) increased with an increase in weight of carcass. However, pH (4 out of 4 muscles), fat (4 out of 5 muscles), and emulsion capacity (5 out 5 muscles) decreased with an increase in weight of carcass. Total collagen showed no effect across all 39 muscles due to weight.

These data indicate a vast amount of variation in physical and chemical properties among muscles of the beef chuck and round. Knowledge of these properties now allows individual muscles to be identified and utilized for production of value-added products.

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