Cow Muscle Profiling: A Comparison of Chemical and Physical Properties of 21 Muscles from Beef and Dairy Cow Carcasses

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Summary

About 43% of the meat from cow carcasses is sold into the boxed beef trade. This research was conducted to compare muscles from beef and dairy cows in an effort to identify optimal uses for cow muscles. Twenty-one muscles from beef and dairy cow carcasses were analyzed for objective color, total heme-iron, total collagen, pH, expressible moisture and proximate composition. Wide variation was observed for all properties measured. Effects of breed type on all measured traits were minimal except in the case of percent moisture. These results indicate muscles from beef and dairy cows are similar in chemical and physical properties. Opportunities exist to upgrade the value of selected cow muscles.

Introduction

Market cows and bulls represent an estimated 25% of the nation's beef production. Nearly 68% of the non-fed cow population consists of beef cows while just over 31% are dairy cows. Previous research has revealed that 43% of the cow carcass is sold as boxed beef, the remaining 57% being merchandised primarily as beef trim for grinding and processing. Though palatability of beef from mature animals has been studied, little research has been performed evaluating chemical and physical properties of a wide variety of muscles from both beef and dairy cow carcasses. Earlier studies have compared carcass traits and meat palatability of beef from animals of beef and dairy breeds. However, research comparing the chemical and physical properties of numerous muscles from both beef and dairy cow carcasses is scarce. Therefore, the objectives of this study were to determine the chemical and physical properties of muscles from beef and dairy cow carcasses and to determine effects of breed type, 12th rib fat thickness, muscling level and skeletal maturity on these properties.

Procedure

One hundred and forty-five cow carcasses (74 beef and 71 dairy) were selected over a 5-month period in 4 geographic locations (Green Bay, WI, Gering, NE, Phoenix, AZ, and Central, FL). Carcasses of a similar weight class were selected based upon breed type (beef or dairy), 12th rib fat thickness (< .1 inch > .1 inch), muscling level (heavy/medium or light) and skeletal maturity (C/D or E). Approximately 5 carcasses were selected for each breed type-fat thickness-muscling level-skeletal maturity combination, of which 21 muscles per carcass were harvested for analysis (see Table 1 for muscle abbreviations). Muscles from 2 carcasses were evaluated for objective color using a Hunter Lab[7] Mini Scan XE plus colorimeter with a 1-inch port. Chemical analysis was performed on muscles from 3 carcasses per cell. A pH meter with spear tip combination 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. Muscle total collagen content is related to the amount of hydroxyproline found in a given muscle

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Table 1. Muscle names and three letter abbreviations

Adductor	ADD
Biceps femoris	BIF
Complexus	COM
Deep pectoral	DEP
Gluteus medius	GLM
Infraspinatus	INF
Latissimus dorsi	LAT
Longissimus dorsi	LOD
Multifidus/Spinalis dorsi	MSD
Psoas major	PSO
Rectus femoris	REF
Semimembranosus	SEM
Semitendinosus	SET
Serratus ventralis	SEV
Supraspinatus	SUP
Teres major	TER
Tensor facia latae	TFL
Triceps brachii	TRB
Vastus intermedius	VAT
Vastus lateralis	VAL
Vastus medialis	VAM

Table 2. Least square means and standard errors for objective color, total heme-iron, and total collagen of beef and dairy market cow muscles.

	L*		a*		b*		Heme-iron, ppm		Total Collagen, mg/g	
Muscle[1]	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
ADD	35.46^{nopq}	(0.59)	30.38^{m}	(0.37)	23.42^{m}	(0.44)	36.67^{mn}	(1.28)	7.65^{mnop}	(1.07)
BIF	35.64^{no}	(0.59)	29.38^{mnop}	(0.37)	22.69^{mnop}	(0.44)	32.90^{opqrs}	(1.28)	12.28^{s}	(1.07)
COM	33.93^{pqrst}	(0.59)	28.98^{opqr}	(0.37)	21.67^{opqr}	(0.44)	35.75^{mnop}	(1.27)	10.69^{qrs}	(1.07)
DEP	34.35^{opqrs}	(0.59)	28.07^{rst}	(0.37)	21.24^{rst}	(0.44)	20.60^{rst}	(1.29)	10.36^{pqrs}	(1.07)
GLM	32.60^{t}	(0.59)	28.34^{qrst}	(0.37)	21.66^{qrst}	(0.44)	35.14^{mnopq}	(1.31)	11.81^{s}	(1.03)
INF	32.70^{t}	(0.58)	30.04^{mn}	(0.37)	23.42^{mn}	(0.44)	35.70^{mnop}	(1.27)	21.66^{u}	(1.07)
LAT	33.10st	(0.60)	27.87^{stu}	(0.38)	20.35^{stu}	(0.45)	31.21^{rst}	(1.32)	8.55^{mnopqr}	(1.17)
LOD	34.75^{opqr}	(0.58)	28.44^{opqrst}	(0.37)	21.96^{opqrst}	(0.44)	30.21st	(1.27)	9.75^{mn}	(1.03)
MSD	32.40^{t}	(0.59)	28.79^{opqrs}	(0.37)	21.74^{opqrs}	(0.44)	37.43^{m}	(1.28)	15.60^{t}	(1.07)
PSO	35.38^{nopq}	(0.59)	26.92^{u}	(0.37)	20.21^{u}	(0.44)	32.75^{opqrs}	(1.34)	6.08^{m}	(1.07)
REF	35.50^{nop}	(0.59)	29.45^{mno}	(0.37)	22.65^{mno}	(0.44)	31.74^{qrs}	(1.29)	8.63^{mnopqr}	(1.03)
SEM	33.39^{rst}	(0.58)	29.01^{opqr}	(0.37)	22.31^{opqr}	(0.44)	32.22^{pqrs}	(1.29)	7.78^{mnopq}	(1.03)
SET	38.43^{m}	(0.59)	28.67^{opqrs}	(0.37)	22.19^{opqrs}	(0.44)	27.64^{t}	(1.28)	8.56^{mnopqr}	(1.12)
SEV	33.85^{qrst}	(0.60)	30.12^{mn}	(0.38)	23.47^{mn}	(0.45)	35.98^{mno}	(1.28)	9.75^{opqrs}	(1.07)
SUP	34.04^{opqrst}	(0.61)	29.33^{nopq}	(0.38)	22.23^{nopq}	(0.46)	34.12^{mnopqr}	(1.28)	10.95^{rs}	(1.17)
TER	36.58^{n}	(0.59)	28.23^{rst}	(0.37)	21.20^{rst}	(0.44)	30.85^{rst}	(1.34)	10.09^{pqrs}	(1.12)
TFL	33.22^{rst}	(0.59)	27.62^{tu}	(0.37)	20.45^{tu}	(0.44)	30.58^{rst}	(1.31)	8.24^{mnopqr}	(1.07)
TRB	32.95st	(0.59)	29.40^{mnop}	(0.37)	22.87^{mnop}	(0.44)	36.95^{m}	(1.28)	9.66^{nopqrs}	(1.07)
VAL	34.54^{opqrs}	(0.58)	28.40^{pqrst}	(0.37)	21.66^{pqrst}	(0.44)	33.32^{nopqrs}	(1.28)	6.98^{mno}	(1.03)
VAM	33.03st	(0.60)	27.76^{stu}	(0.38)	21.31^{stu}	(0.45)	36.63^{mn}	(1.28)	6.15^{m}	(1.03)
VAT	35.40^{nopq}	(0.59)	28.99^{opqr}	(0.37)	22.37^{opqr}	(0.44)	37.12^{m}	(1.29)	9.34^{nopqrs}	(1.07)

[1]Refer to Table 1 for muscle abbreviations.
Values in the same column having different superscripts are significant at $P < 0.05$ level.

Table 3. Least square means and standard errors for pH, expressible moisture, and proximate composition of beef and dairy market cow muscles.

	pH		Expressible Moisture, %		Moisture, %		Fat, %		Ash, %	
Muscle[1]	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
ADD	5.64^{tu}	(0.03)	47.19^{m}	(0.70)	74.78^{pq}	(0.25)	3.57^{qrs}	(0.29)	1.61^{m}	(0.04)
BIF	5.68^{tu}	(0.03)	43.32^{qr}	(0.70)	74.56^{qr}	(0.25)	4.62^{p}	(0.29)	1.54^{mno}	(0.04)
COM	5.92^{pq}	(0.03)	41.74^{stuv}	(0.70)	74.85^{pq}	(0.26)	4.88^{p}	(0.29)	1.36^{tuvw}	(0.05)
DEP	5.67^{tu}	(0.03)	42.88^{rstuv}	(0.70)	75.80^{mno}	(0.25)	3.66^{qr}	(0.29)	1.46^{nopqrst}	(0.04)
GLM	5.67^{tu}	(0.03)	46.30^{mno}	(0.70)	73.71^{s}	(0.25)	5.28^{op}	(0.29)	4.57^{mn}	(0.04)
INF	6.06^{n}	(0.03)	40.96^{uv}	(0.70)	73.85^{s}	(0.26)	5.88^{no}	(0.29)	1.25^{wx}	(0.05)
LAT	5.83^{rs}	(0.03)	43.06^{rst}	(0.73)	76.25^{mn}	(0.27)	3.20^{qrst}	(0.29)	1.43^{opqrstu}	(0.05)
LOD	5.63^{tu}	(0.03)	44.70^{opqr}	(0.69)	73.64^{s}	(0.26)	4.89^{p}	(0.30)	1.52^{mnopqr}	(0.05)
MSD	6.09^{n}	(0.03)	37.42^{w}	(0.70)	72.24^{t}	(0.27)	8.61^{m}	(0.29)	1.20^{x}	(0.05)
PSO	5.77^{s}	(0.03)	44.76^{opqr}	(0.71)	73.70^{s}	(0.25)	6.32^{n}	(0.29)	1.53^{mnopq}	(0.04)
REF	5.85^{qrs}	(0.03)	43.97^{qr}	(0.69)	75.61^{no}	(0.25)	3.40^{qrs}	(0.29)	1.38^{stuv}	(0.04)
SEM	5.60^{u}	(0.03)	46.82^{mn}	(0.70)	74.63^{qr}	(0.25)	3.79^{q}	(0.29)	1.57^{mn}	(0.04)
SET	5.69^{t}	(0.03)	45.07^{nopq}	(0.70)	75.63^{no}	(0.25)	2.84st	(0.29)	1.33^{uvw}	(0.04)
SEV	6.01^{no}	(0.03)	40.81^{v}	(0.70)	73.99^{rs}	(0.26)	6.33^{n}	(0.29)	1.29^{vwx}	(0.05)
SUP	5.96^{op}	(0.03)	42.93^{rst}	(0.70)	76.27mn	(0.26)	3.66^{qr}	(0.29)	1.44^{opqrstu}	(0.05)
TER	5.90^{pqr}	(0.03)	46.32^{mno}	(0.71)	76.35^{m}	(0.25)	3.31^{qrst}	(0.29)	1.41^{qrstuv}	(0.04)
TFL	5.78^{s}	(0.03)	41.12^{tuv}	(0.70)	74.59^{qr}	(0.25)	4.74^{p}	(0.29)	1.42^{pqrstu}	(0.04)
TRB	5.78^{s}	(0.03)	44.16^{pqr}	(0.70)	75.46^{op}	(0.26)	3.57^{qrs}	(0.29)	1.50^{mnopqrst}	(0.05)
VAL	5.78^{s}	(0.03)	45.92^{mnop}	(0.70)	75.75^{mno}	(0.25)	2.89^{rst}	(0.29)	1.53^{mnop}	(0.04)
VAM	5.93^{opq}	(0.03)	43.69^{qr}	(0.70)	77.11^{m}	(0.26)	2.55^{t}	(0.29)	1.40^{qrstuv}	(0.05)
VAT	6.30^{m}	(0.03)	43.39^{qr}	(0.70)	75.89^{mn}	(0.26)	7.45^{p}	(0.29)	1.40^{rstuv}	(0.05)

[1]Refer to Table 1 for muscle abbreviations.
Values in the same column having different superscripts are significant at $P < 0.05$ level.

sample. Hydrochloric acid is added to a sample and subjected to a combination of high pressure and heat to denature the proteins in the sample. Hydroxyproline content then is assayed using a spectrophotometer. Total collagen content is expressed as mg of collagen/g of lean tissue. Total heme-iron is a measurement of pigment (myoglobin and hemoglobin) in a muscle sample. Pigments are extracted using acetone and hydrochloric acid. The total heme content then is quantified using a spectrophotometer and reported in parts per million. Proximate composition consisted of fat, moisture and ash determination and was measured by Soxhlet ether extraction (fat) and a LECO Thermogravimetric Analyzer (moisture and ash). Fat, moisture and ash were reported as a percentage of lean tissue. Data were analyzed using the general linear model procedure of Statistical Analysis System (SAS).

Results

The results of this project are given in Tables 2 and 3. These data indicate large variation in all measured characteristics among the 21 muscles studied. 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. The measurements ranged from 32.40 (MSD) to 38.43 (SET), 26.92 (PSO) to 30.38 (ADD), and 20.21 (PSO) to 23.42 (ADD) for L*, a*, and b*, respectively. Breed type had minimal effects on objective color measurement influencing L* values of only four muscles ($P < 0.05$).

Expressible moisture provides information pertaining to the water holding capacity of various muscles. Low expressible moisture values correspond to greater water holding capacity. Expressible moisture values varied significantly ($P < 0.05$) among muscles ranging from 37.42 (MSD) to 47.19 (ADD). Differences in expressible moisture between muscles from beef and dairy carcasses were observed in only one of the 21 muscles studied ($P < 0.05$).

A wide range of values was observed for all components of proximate analysis. The MSD muscle had the lowest percentage moisture (73.71) and highest percentage fat (8.61). Conversely, VAM had the highest percentage moisture (77.11) and lowest percentage fat (2.55). Ash content ranged from 1.20 (MSD) to 1.61 (ADD and TRB). Eight muscles exhibited significant variation in percentage moisture due to breed type, while the percentage fat and ash of just two and one muscles, respectively, showed significant differences. For all muscles influenced by breed type, percentages of moisture, fat and ash were greater in muscles from beef cows compared to those from dairy cows.

Muscle pH is an indicator of meat quality affecting muscle color, protein functionality and water-holding capacity. Muscles with higher pH values generally exhibit improved water holding capacity, as well as darker color, with the side effect of shorter shelf life. The results of this study show that muscle pH is variable from one muscle to another. A range in values was observed from a low of 5.6 (SEM) to a high of 6.30 (VAT); differences were found to be significant ($P < 0.05$). Muscle pH is dependent on the amount of glycogen present in the muscle at the time of slaughter and can be influenced by animal diet. No significant differences in muscle pH were observed between muscles from beef and dairy cows.

Collagen is a protein found in connective tissues. Large amounts of connective tissue have adverse effects on the tenderness and palatability of meat. In this study a wide range of collagen content was observed. Of the 21 muscles studied, the PSO had the lowest total collagen content (6.08 mg/g) while the INF exhibited the greatest amount (21.66). Collagen has been shown to vary from animal to animal and with animal age. However, only one of the 21 muscles studied showed an effect of either carcass maturity or breed type in this study.

Heme-iron is a measurement of the total pigment (both myoglobin and hemoglobin) in a muscle sample. Heme-iron has been shown to have an effect on muscle color. With the emphasis being placed on enhancing the color stability of fresh meat products, heme-iron is an important property to measure. The concentration of heme-iron varied significantly among the muscles studied ($P < 0.05$), ranging from 27.64 (SET) to 37.43 (MSD). Differences among muscles may be related to the amount of residual blood remaining in the muscle post slaughter, as well as muscle type and function. In general, breed type had little influence on heme-iron content of market cow muscles, significantly affecting only one of the 21 muscles studied.

The results of this study indicate minimal differences exist among muscles from beef and dairy cow carcasses. In general, sorting cow carcasses based on breed type will not alter the mean muscle values of the 10 muscle characteristics studied. A large variation was observed in the chemical and physical attributes of beef and dairy cow muscles. Processors may use these data to identify muscles which exhibit characteristics they desire for certain value-added applications.

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