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Summary

Flavor relationships among muscles and causes of liver-like off-flavor of six muscles from each of 30 beef carcasses were evaluated by a trained sensory panel. The infraspinatus (flat iron) was lowest in sour, metallic, and oxidized flavors and highest in fatty flavor. The vastus lateralis (knuckle side) had the most intense off-flavor and was among the highest for sour and oxidized. Heme iron concentration and pH were lowly related to off-flavor. Of 18 muscles from three carcasses, 16 were high in liver-like off-flavor. These data suggest liver-like off-flavor is related to something that impacts the entire animal.

Introduction

New cuts from the beef round and chuck have gained popularity. There have been anecdotal reports of off-flavors, especially a liver-like flavor, in some beef value cuts. The incidence and intensity of liver-like flavor in various muscles is unknown. Flavor is highly correlated with overall-like ratings in beef. With the importance of flavor to the consumer, it is likely that they will not try the same cut again if they have a bad flavor experience. The objective of this research was to compare different beef muscles for off-flavors and to determine the relationship of pH and heme-iron content to off-flavor.

Procedure

Knuckles and shoulder clods were removed from 16 Choice and 14 Select-grade beef carcasses. Hot carcass weight, fat thickness, marbling, rib-eye area, and percentage kidney, pelvic, and heart (KPH) fat were recorded and yield grade was calculated. The knuckles and shoulder clods were stored in a 33.8°F dark cooler until 7 days postmortem. The rectus femoris (REC; knuckle center), vastus lateralis (VAL; knuckle side), vastus medialis (VAM; knuckle bottom), infraspinatus (INF; top blade or flat iron), teres major (TER; petite tender), and triceps brachii-long head (TRI; clod heart) were fabricated from each carcass. The INF was filleted, and the connective tissue running laterally through the middle of the muscle was removed. Each half of the INF was then cut into three steaks. The TER and VAM were left as whole muscles due to size. A sample was cut from the end of each muscle, minced, and retained for chemical analysis. The VAL, REC, and TRI were cut into 1-inch steaks, wrapped, and frozen at -3°F.

Samples were prepared by cubing, freezing in liquid nitrogen, powdering the frozen sample with a blender, and storing at -112°F. Powdered sample was used to measure moisture content using a LECO Thermogravimetric Analyzer. A pH meter with a spear tip combination electrode was used to determine the pH of the muscle. Hemoglobin and myoglobin were extracted using acetone and hydrochloric acid and then quantified using a spectrophotometer.

Frozen steaks were tempered for 1 day in a 33°F cooler before cooking. The steaks were weighed and trimmed. Each steak was grilled to an internal temperature of 150°F. Thermocouples were inserted in the approximate center of each steak. A hand-held digital thermometer was also used to confirm the internal temperature. Steaks were first turned after two minutes and then flipped as needed to minimize charring.

After reaching the desired internal temperature, the steak was removed from the grill. The steaks were cut into 1 x 2 x 1 inch steak cubes and placed in double broilers until served (< 15 min). The trained panelists received between six and eight samples per session. All eight samples were either from the same muscle type or they were in groups of four from two different muscles. On days that samples from two muscles types were served, a five-minute break was given to separate the two muscles. All steaks were from a consistent location on the muscle. Because of the small size of the TER and VAM, they were cooked as whole muscles. The order of the day that each muscle was served was random and steaks for each muscle were served in random order. Panelists were not aware of which type of steak they were eating.

Panelists used 8-point hedonic rating scales with 8=extremely juicy, extremely tender, no connective tissue and no off-flavor, and 1=extremely dry, extremely tough, abundant amount of connective tissue, and extreme off-flavor. They also identified off-flavor notes including charred, liver-like, metallic, musty/oxidized, acidic, rancid, and sour flavors. Oxidized was described as a "warmed over" flavor and rancid was the flavor associated with lipid oxidation.

Muscle carcass traits and muscle off-flavor traits were analyzed by analysis of variance using the GLM procedure of SAS. Muscle off-flavor notes within flavor group were analyzed by analysis of variance using the MIXED procedure of SAS. The linear and quadratic functions of heme-iron and pH, as well as the interaction, were included in regression equations to obtain the coefficients of determination.

Results

Only percentage KPH fat and marbling differed between Choice and Select cattle, with Choice-grade cattle

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Table 1. The effect of muscle on sensory characteristics, heme-iron concentration, and pH[a,b]

Muscle[c]	Tender (S.E.)	C.T. (S.E.)	Juice (S.E.)	O.F. Intensity (S.E.)	Heme (S.E.)	pH (S.E)
INF	6.50^{de}(0.16)	5.77^{de}(0.17)	6.22^{d} (0.13)	6.03^{d} (0.16)	44.42 (1.97)	5.70^{d} (0.03)
REC	6.11^{e} (0.16)	5.44^{e} (0.17)	5.69^{e} (0.13)	5.68^{e} (0.16)	46.25 (1.97)	5.59^{e} (0.03)
TER	6.58^{d} (0.16)	5.85^{d} (0.17)	6.15^{d} (0.13)	5.41^{ef}(0.16)	42.99 (1.97)	5.71^{d} (0.03)
TRI	5.45^{f} (0.16)	4.32^{f} (0.17)	5.68^{e} (0.13)	5.54^{e} (0.16)	45.43 (1.97)	5.47^{f} (0.03)
VAL	4.66^{g} (0.16)	3.63^{g} (0.17)	5.07^{f} (0.13)	5.10^{f} (0.16)	45.60 (1.97)	5.54^{ef}(0.03)
VAM	5.45^{f} (0.16)	4.18^{f} (0.17)	6.04^{d} (0.14)	5.58^{e} (0.17)	47.47 (2.02)	5.66^{d} (0.03)

[a]Tender=Tenderness, C.T=Connective tissue, Juice=Juiciness, O.F. Intensity=Off-flavor intensity, and Heme=Heme-iron concentration, in ppm.
[b]Taste panel scale: 8=extremely juicy, extremely tender, no connective tissue and no off-flavor, and 1=extremely dry, extremely tough, abundant amount of connective tissue, and extreme off-flavor.
[c] INF=Infraspinatus, top blade or flat iron; REC=rectus femoris, knuckle center; TER=teres major, petite tender; TRI=triceps brachii-long head, clod heart; VAL=vastus lateralis, knuckle side; VAM=vastus medialis, knuckle bottom.
[defg] Means within a column (for sensory traits) with different superscripts are significantly ($P < 0.05$) different.

Table 2. The effect of muscle on percentage of panelists detecting each off-flavor note[a]

Muscle	Liver (S.E.)	Sour (S.E.)	Metallic (S.E.)	Char (S.E.)	Bloody (S.E.)	Oxid. (S.E)	Fatty (S.E)	Rancid (S.E)
INF	9.3 (2.9)	23.2^{c} (3.7)	8.7^{c} (2.2)	29.9^{d} (4.4)	1.6 (1.0)	9.5^{cd} (2.3)	14.0^{d} (1.3)	8.8 (1.6)
REC	9.7 (2.9)	44.2^{d} (3.7)	13.4^{c} (2.2)	20.4^{cd}(4.4)	3.4 (1.0)	7.4^{c} (2.3)	3.2^{c} (1.3)	4.9 (1.6)
TER	8.8 (2.9)	48.7^{d} (3.7)	15.5^{cd}(2.2)	21.6^{cd}(4.4)	1.8 (1.0)	8.5^{cd} (2.3)	3.3^{c} (1.3)	5.8 (1.6)
TRI	7.7 (2.9)	49.5^{d} (3.7)	19.5^{d} (2.2)	22.2^{cd}(4.4)	0.8 (1.0)	13.3^{cde}(2.3)	1.6^{c} (1.3)	5.6 (1.6)
VAL	9.1 (2.9)	48.4^{d} (3.7)	15.0^{cc}(2.2)	30.5^{d} (4.4)	1.3 (1.0)	17.5^{e} (2.3)	1.4^{c} (1.3)	6.8 (1.6)
VAM	10.8 (3.0)	49.0^{d} (3.8)	17.3^{cd}(2.2)	14.8^{c} (4.6)	2.9 (1.0)	14.6^{de} (2.3)	2.3^{c} (1.4)	7.2 (1.6)

[a]Liver=Liver-like, Char=Charred\bitter, Oxid=Oxidized.
[b] INF=Infraspinatus, top blade or flat iron; REC=rectus femoris, knuckle center; TER=teres major, petite tender; TRI=triceps brachii-long head, clod heart; VAL=vastus lateralis, knuckle side; VAM=vastus medialis, knuckle bottom.
[cde] Means within a column (for sensory traits) with different superscripts are significantly ($P < 0.05$) different.

having a greater amount of both. This result is expected because carcasses are sorted into quality grades based primarily on marbling.

Off-flavor intensity differed among muscles (Table 1). The INF had the lowest off-flavor intensity (a higher numerical score) and was among the most tender and juicy of the muscles tested. The VAL had the most intense off-flavor ratings (lower numerical scores) and was the least tender, had the most connective tissue, and had the lowest amount of juiciness ($P < 0.05$). This could be due to a "halo effect" where a sample that has a good flavor is rated more tender or juicy than one with bad flavor. The INF, TER, and VAM had the highest pH values of the muscles tested. There were no differences ($P < 0.05$) among muscles for heme-iron concentration.

Liver-like, bloody, and rancid flavors were not affected by muscle type (Table 2). The INF, which had the lowest amount of off-flavor, was among the lowest in percentage of panelists detecting sour, metallic, and oxidized flavors, although it received a higher rating of fatty flavor than the other muscles ($P < 0.05$). The VAL, which had the most intense off-flavor, was among the highest in percentage of panelists detecting sour, charred, and oxidized flavors ($P < 0.05$). Most of the other muscles were rated as being intermediate in the percentage of panelists detecting specific off-flavor notes. When the off-flavor intensity scores were assessed, it became obvious that when one muscle of a given carcass was off-flavored, all muscles were off-flavor (Table 3). Sixteen of the 18 muscles from animals six, seven, and nine had off-flavor intensity scores below five.

In an attempt to explore the off-flavor intensity ratings among these muscles, the muscles were grouped. All muscles where at least 30% of the panelists recognized the off-flavor as liver-like were classified as "off-flavor" while the other muscles were classified as "normal." There were no group by muscle interactions for sour, metallic, fatty, bloody, or oxidized off-flavor notes. The percentage of panelists detecting liver-like scores was very high which is to be expected, as this is how they were grouped (Table 4). Charred flavors were lower for the off-flavor group than for the normal group ($P < 0.05$). This could be because the intense liver-like flavor overwhelms the charred flavor. There was also an interaction among rancid samples that was only significant for the VAM, where off-flavor samples were less rancid than normal samples ($P < 0.05$). This suggests that liver-like flavor is not associated with other off-flavor notes.

Regression equations containing the linear and quadratic functions of heme-iron concentration, muscle pH, and their interaction were established for the frequency of off-flavor notes within each muscle for each quality grade (data not shown). Within Choice, only the VAL and INF showed a relationship between pH, heme, and

Table 3. Off-flavor intensity scores among muscles[a,b]

Animal	Grade	INF	TER	TRI	REC	VAL	VAM
1	Choice	6.36	4.20	6.06	6.44	5.58	5.25
2	Choice	6.25	6.17	6.00	5.75	5.14	5.65
3	Choice	6.75	6.45	6.31	6.78	5.44	6.05
4	Choice	7.19	5.44	6.11	6.75	5.86	6.33
5	Choice	6.61	5.00	5.56	6.75	5.72	5.65
6	Choice	4.17	2.55	3.56	3.83	3.36	3.10
7	Choice	4.38	3.39	4.39	3.31	4.14	4.90
8	Choice	6.07	6.05	4.89	6.38	4.86	5.50
9	Choice	4.56	5.35	5.06	4.94	4.60	4.00
10	Choice	6.55	5.33	4.88	6.31	4.56	6.22

[a]Taste panel scale: 8=no off-flavor and 1=extreme off-flavor.
[b] INF=Infraspinatus, top blade or flat iron; REC=rectus femoris, knuckle center; TER=teres major, petite tender; TRI=triceps brachii-long head, clod heart; VAL=vastus lateralis, knuckle side; VAM=vastus medialis, knuckle bottom.

Table 4. The effect of normal vs. off-flavor group[a] and muscle on percentage of panelists detecting each off-flavor note

Muscle[b]	Liver-like		Charred		Rancid	
	Normal (S.E.)	Off-flavor (S.E.)	Normal (S.E.)	Off-flavor (S.E.)	Normal (S.E.)	Off-flavor (S.E.)
INF	3.6[d] (1.5)	83.3[c] (5.4)	5.6 (15.7)	31.7 (4.3)	0 (6.0)	9.5 (1.6)
REC	5.1[d] (1.5)	48.2[c] (4.4)	23.2 (13.2)	20.6 (4.3)	7.9 (4.9)	4.6 (1.6)
TER	4.0[d] (1.5)	48.9[c] (4.4)	69.1[c](13.2)	16.9[d](4.3)	6.7 (4.9)	6.0 (1.6)
TRI	5.2[d] (1.5)	41.0[c] (5.4)	52.1[c](15.7)	19.7[d](4.3)	5.2 (6.0)	5.7 (1.6)
VAL	4.4[d] (1.5)	47.6[c] (4.4)	64.9[c](13.2)	26.9[d](4.3)	13.1 (4.9)	6.2 (1.6)
VAM	5.0[d] (1.5)	60.0[c] (4.4)	20.0 (13.2)	14.9 (4.5)	23.3[c](4.9)	5.3[d](1.7)

[a]Muscles where at least 30% of the panelists detected liver-like off-flavor were classified as off-flavor; all others were classified as normal.
[b] INF=Infraspinatus, top blade or flat iron; REC=rectus femoris, knuckle center; TER=teres major, petite tender; TRI=triceps brachii-long head, clod heart; VAL=vastus lateralis, knuckle side; VAM=vastus medialis, knuckle bottom.
[cd] Means within a row for a given off-flavor with different superscripts are significantly ($P < .05$) different.

bloody flavor ($P < 0.05$). There were no significant relationships between pH, heme-iron concentration, and metallic flavors or oxidized flavors for either Choice or Select-grade muscles. Muscles from Select-grade carcasses had stronger relationships between off-flavor notes and pH and heme-iron, possibly because the three carcasses with strong, liver-like off-flavor were Select. Heme-iron and pH explained some of the off-flavor intensity of the TER, VAL, and VAM ($P < 0.05$).

Bloody flavor notes in the TRI showed a relationship ($P = 0.003$) for heme-iron concentration and pH. Heme-iron concentration and pH influenced liver flavor ($P = 0.0003$) and sour flavor ($P = 0.042$) in the REC. Liver-like flavor in the VAM was also influenced ($P = 0.042$). Heme-iron concentration and pH influenced charred flavor ($P = 0.032$) and rancid flavor ($P = 0.042$) in the TER.

Conclusion

When one muscle from a carcass contained liver-like off-flavor, the other muscles tested from that same carcass also contained that flavor. This suggests liver-like flavor is related to something the entire animal experiences, like genetics, a feedstuff, or a pharmaceutical product. It is unknown if muscles other than those tested here would also have the off-flavor. Muscles from the chuck and round have different off-flavor amounts as well as different sensory characteristics. There appears to be only a slight relationship between heme-iron concentration, pH and off-flavor.

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