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Review

Impact of grass/forage feeding versus grain finishing on beef nutrients and sensory quality: The U.S. experience

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ABSTRACT

Studies of forage and/or grass feeding of cattle versus grain finishing have been conducted in varying regions throughout the world but generalization of these results to beef from U.S. cattle may not be appropriate. In particular, available grass/forage variety and form as well as cattle breed have a significant impact on the nutritional profile of beef. The current review summarizes the nutritional characteristics of beef as reported from the limited number of studies comparing U.S. grass/forage-fed versus grain-finished cattle and estimates the intake of key nutrients that might be expected from consumption of U.S. beef from either feeding system. In addition, many studies report changes in fatty acids solely as a percentage of total fatty acids. Since grass/forage feeding typically results in a leaner product; the current review compares the fatty acid profile of beef from grass/forage feeding to that of grain-finished cattle on a mg/100 g of meat basis.

Contents

1. Introduction . . . 535
2. Fats and fatty acids . . . 536
   2.1. Total fat and cholesterol . . . 536
   2.2. Fatty acid profile . . . 536
   2.3. Saturated fatty acids . . . 536
   2.4. Monounsaturated fatty acids . . . 537
   2.5. Polyunsaturated fatty acids . . . 537
   2.6. Conjugated linoleic acid . . . 538
3. Other nutrients . . . 538
   3.1. Antioxidants . . . 538
   3.2. Trace minerals and B vitamins . . . 539
   3.3. Protein . . . 539
4. Sensory quality . . . 539
5. Conclusions . . . 539
Funding/support disclosure . . . 539
Author disclosure statement . . . 539
References . . . 539

1. Introduction

The reasons that U.S. consumers state for purchasing beef from "grass fed" cattle vary and are based largely on perceptions including promotion of animal health and well-being, environmental sustainability, and/or production of meat products with a modified nutritional profile

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(United States Department of Agriculture, Agricultural Marketing Service, 2007) particularly with regard to a lower total fat content and more healthful fatty acid profile. The majority of whole muscle beef cuts sold in U.S. retail markets are lean with 15 of the top 20 most popular cuts meeting U.S. FDA criteria for lean labeling (McNeill, Harris, Field, & Van Elswyk, 2012). Certification through the United States Department of Agriculture's (USDA) Agricultural Marketing Service (AMS) voluntary labeling program does not guarantee a particular nutrient profile but does guarantee that beef marketed as "grass (forage) fed" will be from cattle fed grass and forage throughout "… the lifetime of the ruminant animal, with the exception of milk consumed prior to weaning."(United States Department of Agriculture, Agricultural Marketing Service, 2007) Additionally, "Animals cannot be fed grain or grain byproducts and must have continuous access to pasture during the growing season" (United States Department of Agriculture, Agricultural Marketing Service, 2007). Allowance for the feeding of high quality dried grass (hay) and legumes (alfalfa) as well as silage is also recognized for grass/forage-fed cattle in the U.S. owing to periods of zero pasture growth (United States Department of Agriculture, Agricultural Marketing Service, 2007). U.S. beef labeled as grass-fed but *not* bearing USDA certification may be the result of various combinations of grass and grain feeding including grass finishing.

To date, systematic reviews of the scientific literature regarding nutrient profile of beef from "grass fed" cattle have either combined the results from studies conducted throughout the world (Daley, Abbott, Doyle, Nader, & Larson, 2010), throughout Europe (Scollan et al., 2006) or focused on those from one of several countries practicing primary fresh pasture feeding (Ponnampalam, Mann, & Sinclair, 2006). The meat nutritional profile resulting from fresh pasture feeding systems in countries with abundant grass growing seasons, such as Brazil, Argentina, Uruguay, Australia and New Zealand is not directly applicable to beef marketed as "grass fed" in the U.S. In particular, heterogeneity exists between countries with regard to pasture type and availability and cattle breeds, all with the potential to influence the nutrient composition of the cattle diet and thus affect meat nutritional and sensory quality (Luciano et al., 2011; Mir, Bittman, Hunt, Entz, & Yip, 2006). The current review summarizes the nutritional characteristics of beef from the limited number of studies comparing the variety of regimes contributing to U.S. grass/forage-fed beef versus grain-finished beef and estimates the intake of key nutrients that might be expected from consumption of beef from either system in the U.S. In addition, since grass/forage feeding typically results in a leaner product (Daley et al., 2010), the current review summarizes the nutritional characteristics of beef from U.S. grass/forage-fed and grain-finished cattle on a mg/100 g rather than a percentage of total fat basis.

2. Fats and fatty acids

2.1. Total fat and cholesterol

Reducing external carcass fat of beef has been one of the major breeding goals for the U.S. beef industry over the past 30 years (McNeill et al., 2012). A review on the topic (DeSmet, Raes, & Demeyer, 2004) confirms individual reports (Itoh, Johnson, Cosgrove, Muir, & Purchas, 1999) that beef fat deposition is highly heritable and as such, total fat content may differ significantly among breeds. Stage of growth is also influential on total carcass fat with certain breeds depositing more total fat and particular fatty acids at an early stage of life than other breed types (DeSmet et al., 2004). Therefore, the total fat content of beef reflects not only feeding regime but also genetic variability between cattle breeds, age at harvest, carcass grade, and beef cut.

It has been proposed that the cholesterol content of beef from grass-fed cattle would be lower than that from grain-finished (Daley et al., 2010). However, only one U.S. based study (Rule, Broughton, Shellito, & Maiorano, 2002) has reported a statistically significant difference in the cholesterol content of beef from grass/forage-fed and grain-finished cattle [Table 1]. This difference in cholesterol content, in the context of a 230 g (8 oz) steak, results in an estimated 20 mg reduction in dietary cholesterol intake compared to the same cut from a grain-finished animal.

In contrast, evidence from four U.S. studies regarding the effect of grass feeding or finishing on total carcass fat content suggests that grass/forage feeding significantly lowers total fat compared to grain-finished cattle [Table 2]. When comparing available evidence for lean cuts, this reduction translates to a 2–4 g difference in total fat per 100 g grass-fed vs. grain-finished beef, as consumed [Table 2]. Only Lorenzen et al. (2007) report carcass grade, with either regime resulting in a grade of Select. Feeding systems that rely on grain-finishing maximize the availability of net energy and glucose for fat synthesis as muscle growth declines in older animals thus contributing to a higher fat content than can be achieved by grass feeding or finishing (Scollan et al., 2006).

2.2. Fatty acid profile

The effect of grass feeding on the fatty acid profile of beef cannot be generalized easily. It appears that various meat fatty acids are influenced by both breed and type of grass. For example, two common U.S. cattle breeds, Angus and Simmental, have been reported to divergently deposit certain saturated fatty acids (SFAs) in response to feeding annual vs. perennial grasses. Specifically, Angus cattle grazed on annual pasture (rye grass, red clover, lotus) deposited higher levels of stearic acid in polar lipids of intramuscular fat, after adjusting for differences in intramuscular fat concentration, than did annual pasture-fed Simmental cattle (Itoh et al., 1999). It also has been reported that the fatty acid profile of individual muscles responds differently to grass feeding or grain finishing with, for example, significantly less monounsaturated fatty acid (MUFA) deposited in *Semimembranosus* (top round) of grass-fed cattle but similar MUFA in *Triceps brachii* (shoulder center) and *Longissimus lumborum* (loin eye) of grass-fed and grain finished cattle (Lorenzen et al., 2007). The level of fatness also has an effect on the fatty acid composition of beef with "lean breeds" (e.g. double-muscle animals) yielding meat with higher polyunsaturated fatty acid (PUFA) content than other breeds regardless of background diet (DeSmet et al., 2004) because the greatest abundance of PUFA in beef is located in the phospholipids of muscle membranes. Finally, meat fatty acid composition can also vary depending on fat type/location, i.e. marbling vs. seam fat (Jiang et al., 2010).

2.3. Saturated fatty acids

Regardless of feeding regime, approximately one-third of the SFA in beef is stearic acid, a fatty acid shown to be neutral with regard to plasma LDL cholesterol. The neutral effect of stearic acid on LDL cholesterol has been confirmed by many world-wide health organizations that distinguish stearic acid from cholesterol-raising saturated fats (Dietary Guidelines Advisory Committee, 2010; Food and Agriculture Organization of the United Nations, 2010; Institute of Medicine, 2005). In fact, the U.S. Dietary Guidelines Advisory Committee (DGAC) has

Table 1
Cholesterol (mg/100 g beef) content of U.S. beef in response to grass/forage feeding or grain finishing.

Publication	Beef cut	Grass	Grain
Duckett et al. (2013)	Steak — ribeye, strip, Delmonico	56.9	57.2
Duckett et al. (2009)	Steak — ribeye, strip, Delmonico	57.3	56.3
Leheska et al. (2008)	Steak — strip	54.7	54.6
Rule et al. (2002)	Steak — ribeye, strip, Delmonico	52.3	52.7
Rule et al. (2002)	Round cuts — eye of, outside	48.7	53.4[a]
Rule et al. (2002)	Tenders — mock, chuck, Scotch	52.7	61.4[a]

[a] Statistically different from grass-fed.

Table 2
Comparison of total and saturated fatty acid content [a] of U.S. beef from grass/forage-fed or grain-finished cattle.

Publication, beef cut	C12:0 Lauric acid	C14:0 Myristic acid	C16:0 Palmitic acid	C18:0 Stearic acid	Total saturated fatty acids[b]	Total fat
Duckett et al. (2013), steak — ribeye, strip, Delmonico						
Grain-finished	NR[c]	0.159	1.52	0.740	2.42 (42.4%)[d]	6.7
Grass-finished	NR	0.054	0.567	0.371	0.992 (44.7%)	2.6
Duckett et al. (2009), steak — ribeye, strip, Delmonico						
Grain-finished	NR	0.095	0.901	0.474	1.47 (43.4%)	4.1
Grass-finished	NR	0.048	0.477	0.341	0.866 (44.2%)	2.3
Leheska et al. (2008), steak — strip						
Grain-finished	0.026	0.127	0.971	0.488	1.61 (45.1%)	4.4
Grass-fed	0.011	0.067	0.632	0.400	1.11 (48.8%)	2.8
Lorenzen et al. (2007), combined average of ribeye, round, chuck						
Grain-finished	NR	NR	NR	NR	1.80 (37.8%)	5.7
Grass-fed	NR	NR	NR	NR	1.29 (41.6%)	3.7

[a] Calculated according to Rhee (1994), g/100 g beef.
[b] Combined total of 12:0, 14:0, 16:0, and 18:0.
[c] NR = not reported.
[d] Total as reported in original study, % of fatty acids.

proposed the classification of "cholesterol-raising fatty acids" defined as "SFA with carbon chain lengths from C12 to C16 (i.e. excluding stearic acid and smaller SFA) and trans fatty acids", in particular, industrially derived trans fats (Dietary Guidelines Advisory Committee, 2010). Importantly, this definition excludes naturally occurring trans fats found in foods derived from ruminant animals. Dietary ruminant-derived trans fats may play a role in reducing the risk of chronic disease and are discussed further in Section 2.6.

Four U.S. studies have reported the influence of grass/forage feeding or finishing vs. grain finishing on saturated fat deposition in various cuts of beef, primarily lean steaks (Table 2). When reported on a percentage of total fatty acid basis, U.S. studies have consistently reported increases in total saturated fat deposition in response to grass feeding and finishing (Table 2). However, due to the lower total fat content of beef from grass-fed cattle, this percentage increase does not translate to an increased intake of total SFA from grass-fed beef. In fact, g/100 g beef data suggest that because of its lower total fat content, U.S. grass-fed beef contains up to 1.4 g less total saturated fat per 100 g in various steak cuts than beef from grain-finished cattle (Table 2). It would also appear from the data of Leheska et al. and Duckett, Neel, Fontenot, and Clapham (2009); Duckett, Neel, Lewis, Fontenot, and Clapham (2013) that grass-fed beef may provide a greater amount of SFA as neutral stearic acid when compared to grain-finished beef in various steak cuts. More studies are needed to better understand the contribution of grass/forage-fed beef, from a greater variety of beef cuts, to saturated fat intake in the U.S.

2.4. Monounsaturated fatty acids

Beef is a primary source of MUFA in the U.S. diet and one of the most common sources of MUFA in the form of oleic acid (18:1 n-9) (National Cancer Institute, 2010). Oleic acid increases in beef as marbling fat cells differentiate. U.S. grass-fed cattle produce beef with 30–70% less MUFA, compared to beef from grain-finished cattle (Table 3). This observation may be due, at least in part, to an effect of grass-based diets on desaturase enzyme activity and subsequent decreased MUFA deposition (Smith et al., 2006). The reduction in total MUFA is estimated to be as much as 1.8 g less MUFA per 100 g (average = 0.990 g) beef in U.S. grass/forage-fed beef as compared to grain-finished beef (Table 3).

The role of MUFA in cardiovascular health is well documented. Recent expert reports rate the evidence as "convincing/strong" that substitution of dietary MUFA for cholesterol-raising saturated fatty acids reduces LDL and lowers risk of type II diabetes and cardiovascular disease (Dietary Guidelines Advisory Committee, 2010; Food and Agriculture Organization of the United Nations, 2010). Replacing carbohydrates with MUFA increases HDL (Food and Agriculture Organization of the United Nations, 2010) and, in individuals with type II diabetes, improves markers of glucose tolerance and diabetic control (Dietary Guidelines Advisory Committee, 2010). Results from two recent randomized controlled trials (RCTs) suggest that the higher MUFA content of grain-finished beef may be important for increasing plasma HDL cholesterol among beef consumers and that exclusive grass-feeding could shift the MUFA:SFA ratio of beef in a manner that significantly lowers HDL, increases triglycerides, and increases the density of LDL particles among consumers of grass-fed beef (Adams, Walzem, Smith, Tseng, & Smith, 2010; Gilmore et al., 2011).

2.5. Polyunsaturated fatty acids

The PUFA content of beef is low only averaging up to 5% of total fatty acids (Scollan et al., 2006). The omega-6 fatty acid, linoleic acid (18:2 n-6), is the primary PUFA in both U.S. grass/forage-fed and grain-finished beef (Table 4) providing 60–85% of total PUFA.

Table 3
Comparison of the monounsaturated acid content [a] of U.S. beef from grass/forage-fed or grain-finished cattle.

Publication, beef cut	C14:1 Myristicoleic acid	C16:1 Palmitoleic acid	C18:1 Oleic acid	Total monounsaturated fatty acids[b]
Duckett et al. (2013), steak — ribeye, strip, Delmonico				
Grain-finished	0.038	0.207	2.37	2.61 (46.0%)[d]
Grass-finished	0.009	0.058	0.722	0.789 (36.0%)
Duckett et al. (2009), steak — ribeye, strip, Delmonico				
Grain-finished	0.025	0.120	1.29	1.43 (42.0%)
Grass-finished	0.007	0.054	0.606	0.667 (34.0%)
Leheska et al. (2008), steak — strip				
Grain-finished	0.030	0.141	1.42	1.59 (46.2%)
Grass-fed	0.013	0.076	1.00	1.09 (42.5%)
Lorenzen et al. (2007), combined average of ribeye, round, chuck				
Grain-finished	NR[c]	NR	NR	1.95 (40.7%)
Grass-fed	NR	NR	NR	1.05 (33.8%)

[a] Calculated according to method of Rhee (1994), g/100 g beef.
[b] Combined total of 14:1, 16:1, and 18:1.
[c] NR = not reported.
[d] Total as reported in original study, % of fatty acids.

Table 4
Comparison of the polyunsaturated fatty acid content[a] of U.S. beef from grass/forage-fed or grain-finished cattle.

Publication, beef cut	C18:2 n-6 Linoleic acid	C20:4 n-6 Arachidonic acid	C18:3 n-3 α-Linolenic acid	C20:5 n-3 Eicosapentaenoic acid	C22:5 n-3 Docosapentaenoic acid	C22:6 n-3 Docosahexaenoic acid	Total PUFA	Total n-6 PUFA[b]	Total n-3 LCPUFA[c]
Duckett et al. (2013), steak — ribeye, strip, Delmonico									
Grain-finished	0.152	0.030	0.013	0.005	0.012	0.002	0.214 (3.8)%[d]	0.182	0.019
Grass-finished	0.058	0.020	0.026	0.012	0.019	0.002	0.137 (6.2%)	0.078	0.033
Duckett et al. (2009), steak — ribeye, strip, Delmonico									
Grain-finished	0.101	0.025	0.013	0.004	0.008	0.001	0.152 (4.5%)	0.126	0.013
Grass-finished	0.053	0.002	0.021	0.009	0.014	0.001	0.100 (6.0%)	0.055	0.024
Leheska et al. (2008), steak — strip									
Grain-finished	0.087	0.006	0.004	<0.001	0.002	<0.001	0.099 (2.8%)	0.093	>0.002–≤0.004
Grass-fed	0.047	0.007	0.016	<0.001	0.005	<0.001	0.075 (3.4%)	0.054	>0.005–≤0.007

[a] Calculated according to Rhee (1994), g fat/100 g beef.
[b] n-6 polyunsaturated fatty acids, combination of 18:2 n-6 and 20:4 n-6.
[c] n-3 long-chain polyunsaturated fatty acids, combination of 20:5 n-3, 22:5 n-3, 22:6 n-3.
[d] Total as reported in original study, % of fatty acids.

The percentage PUFA in beef is increased by as much as 25% in response to grass-feeding (Daley et al., 2010). Due to the lower total fat content of most grass-fed beef, however, the total estimated amount of PUFA in steak from U.S. grass/forage-fed cattle may be up to 75 mg lower per 100 g of beef than that of grain-finished beef, primarily as less linoleic acid (Table 4). Of the omega-3 fatty acids, small increases in the short-chain omega-3 fatty acid, linolenic acid (18:3 n-3; ALA), are noted with estimated mg/100 g beef amounts ranging from 16 to 26 mg ALA in various lean cuts for grass/forage-fed versus 4–13 mg ALA from U.S. grain-finished beef. Only trace increases in the longer-chain omega-3 fatty acids (n-3 LCPUFA) characteristic of fish, eicosapentaenoic acid (20:5 n-3; EPA), docosapentaenoic acid (DPA; 22:5 n-3), and docosahexaenoic acid (22:6 n-3; DHA), are noted in meat from U.S. grass/forage-fed cattle (Table 4). While the contribution of ALA to cardiovascular health is debatable (Calder et al., 2010), evidence regarding the role of n-3 LCPUFA in the prevention of heart disease is convincing (Food and Agriculture Organization of the United Nations, 2010). ALA intake by Americans is adequate (Institute of Medicine, 2005), averaging 1.6 g/day, but intake of n-3 LCPUFA is limited, averaging 130 mg or less per day (United States Department of Agriculture, Agricultural Research Service, 2011). Due to the importance of n-3 LCPUFA for cardiovascular health, intake recommendations around the world are for a minimum of 250 mg EPA + DHA/day (European Food Safety, 2010; Food and Agriculture Organization of the United Nations, 2010; United States Department of Agriculture & U.S. Department of Health and Human Services, 2010). Interestingly, it appears that both grain-finished and grass/forage-fed beef can contribute n-3 LCPUFA to the U.S. diet, averaging between 2–19 mg per 100 g and 5–33 mg per 100 g, respectively, primarily as EPA + DPA (Table 4). While EPA and especially DHA intake has been associated with improved cardiovascular health (United States Department of Agriculture & U.S. Department of Health and Human Services, 2010) little is known about the health benefits of DPA alone or EPA + DPA. The inability to accumulate significant amounts of n-3 LCPUFA in beef is due both to biohydrogenation of dietary unsaturated fatty acids by the rumen in an effort to maintain normal rumen function and a limited ability of most mammals to convert EPA to DHA (Scollan et al., 2006). Protection of concentrated PUFA sources such as flaxseed and fish oil using a variety of methods including heat/chemical treatment of whole/processed oilseeds, chemical treatment of oils to create calcium soaps, and emulsification/encapsulation of oils with protein has resulted in modestly improved EPA and DPA but not DHA deposition (Scollan et al., 2006). Use of these feeding techniques has not yet been commercialized in the U.S. It appears that lean cuts from either feeding regime can make a modest contribution to n-3 LCPUFA intake goals while contributing a limited amount of total fat to the diet. In fact, recent RCTs confirm the contribution of red meat, grain and/or grass-fed, to circulating plasma levels of n-3 LCPUFA in healthy adults (McAfee et al., 2011; Welch, Shakya-Shrestha, Lentjes, Wareham, & Khaw, 2010).

2.6. Conjugated linoleic acid

Conjugated linoleic acid (CLA) refers to a group of positional and geometric isomers of linoleic acid characterized by conjugated dienes. CLA is a metabolic end product of the rumen biohydrogenation of linoleic acid and thus accumulates in the fat and muscle of ruminant animals. CLA is also derived in ruminant animals by the delta-9 desaturation of *trans*-vaccenic acid to *cis*-9, *trans*-11 CLA; the predominant CLA isomer in both grass/forage-fed and grain-finished beef is cis-9, trans-11 CLA. Benefits attributed to mixed CLA isomer intake include reduced markers of atherosclerosis (Mitchell & McLeod, 2008) and changes in various cancer-related outcomes in animal models and cell lines (Kelley, Hubbard, & Erickson, 2007). Grass/forage feeding significantly increases the percent of CLA, mainly cis-9, trans-11, in total fatty acids up to twice that found in grain-finished beef (Daley et al., 2010; Duckett et al., 2009; Lorenzen et al., 2007). However, due to the lower total fat content of most grass-fed beef, the total amount of CLA from either grass/forage-fed or grain-finished U.S. beef is essentially identical and either makes only a minor contribution to CLA intake levels found beneficial in clinical trials. For example, RCTs investigating the lipid lowering effects of CLA generally provide mixed CLA isomers ranging from 0.59 g/day to 20 g/day, averaging 5.8 g/day (Gebauer et al., 2011). In contrast, typical dietary intake of vaccenic acid and cis-9, trans-11 CLA combined varies from 1.1 to 1.8 g/day (Gebauer et al., 2011). A 100 g serving of either grain-finished or grass/forage-fed beef may only provide an average of 20 mg total isomers of CLA [calculated from Lorenzen et al., 2007].

3. Other nutrients

3.1. Antioxidants

Antioxidants are compounds that have the capability to inhibit oxidative damage at the cellular level in vivo. Only two studies in the current review have reported levels of antioxidant nutrients in response to grass vs. grain-finishing (Duckett et al., 2009, 2013). Both studies reported increases in common antioxidants, α-tocopherol and β-carotene, in beef from cattle grazing pasture in the U.S. Specifically, in response to grass-finishing, the concentration of α-tocopherol nearly tripled and β-carotene content increased by 1.5 (Duckett et al., 2009) to 10 times (Duckett et al., 2013) as compared to beef from U.S. grain-finished cattle although only the results reported by Duckett et al., 2009 were statistically significant.

3.2. Trace minerals and B vitamins

Duckett et al. (2009, 2013) compared the trace mineral content of grain-finished vs. grass-finished beef and reported no nutritionally relevant difference between the feeding regimes. Compared to beef from U.S. grain-finished cattle, calcium and potassium were significantly higher in grass/forage-finished beef but the respective 2 mg and 12 mg increases would not be meaningful on a total diet basis (Duckett et al., 2009). There are no reported differences in the content of zinc or iron between the feeding regimes. Duckett et al. (2009) reported 7 mg more sodium per 100 g of beef (165 mg vs. 172 mg) from grass/forage-finished beef and twice that reported by Leheska et al. (2008) (61 mg/100 g) for grass/forage-fed beef. In contrast, Duckett et al. (2013) reported on average half the level of sodium reported by Leheska et al. (2008) for grass-finished beef and one-quarter the amount reported in their 2009 study. Leheska et al. (2008) noted that mineral content of grass-fed beef may vary in forage due to the mineral content of the soil in which it is grown. Therefore, whereas the grass species and stage of maturity impact the fatty acid profile of grass-fed beef, the mineral content of the soil, and in particular the sodium content, will impact trace minerals in beef from grass-fed cattle. Among U.S. studies, only Duckett et al. (2009) have compared the riboflavin and thiamine content of grass/forage-finished vs. grain-finished beef and have reported nearly twice the riboflavin and three times the thiamine in beef from grass-finished cattle. Thus grain-finished beef and grass/forage-fed beef provide 2.1–6.1% of the U.S. recommended adult dietary allowance (RDA) for thiamine and 19–38% of the adult RDA for riboflavin per 100 g serving of beef, respectively (IOM, 2000).

3.3. Protein

Animal production factors such as nutrition and genetics have no influence on the protein content or amino acid profile of beef (Scollan et al., 2006). Only a handful of U.S. studies compared protein content of grass/forage-fed to grain-finished cattle (Duckett et al., 2009, 2013; Leheska et al., 2008) and none reported statistical or practical differences (range 20–23%) in response to feeding regime.

4. Sensory quality

Changing the fatty acid composition of beef, particularly the PUFA content, can affect the color, shelf life, and sensory attributes of meat (Scollan et al., 2006). Some U.S. grass/forage-feeding studies (Hedrick et al., 1983; May, Dolezal, Gill, Ray, & Buchanan, 1992; Schroeder, Cramer, Bowling, & Cook, 1980; Sitz, Calkins, Feuz, Umberger, & Eskridge, 2005), but not all (Duckett et al., 2009, 2013; Reagan, Carpenter, Bauer, & Lowrey, 1977), report steaks from grass/forage-fed beef to be less tender than steaks from grain-finished beef while most have found grass/forage- and grain-fed beef to be of similar juiciness (Crouse, Cross, & Seideman, 1984; Duckett et al., 2013; May et al., 1992; Reagan et al., 1977; Schroeder et al., 1980). The effect of grass/forage-feeding on tenderness as reported by Realini et al. (2005) appears dependent, at least in part, on type of pasture and muscle type. While not all U.S. feeding studies have reported quality data, Leheska et al. (2008) and Duckett et al., 2013 report significantly increased yellowness of external fat with grass/forage feeding likely related to the 1.5–10 times increase in adipose B-carotene deposition reported in response to grass/forage-feeding (Duckett et al., 2009, 2013).

Flavor acceptability may be related to individual preference or cultural norms; for example, U.S. consumers seem to prefer the flavor of grain-finished beef while consumers in other countries find the flavor of grass/forage-fed animal preferable (Scollan et al., 2006; Sitz et al., 2005). Flavor will vary depending on the type and maturity of forage, cattle breed, fat content and marbling score so it is difficult to compare the flavor of beef from grass/forage-fed and grain-finished cattle. U.S. consumers participating in a flavor panel described the flavor of ground beef from grass/forage-fed cattle as lacking beef flavor with an intense dairy-milky flavor often accompanied by a soured dairy flavor and/or other off-flavors (Melton, Amiri, Davis, & Backus, 1982). Although Melton et al. (1982) do not report marbling score, because the product tested was ground beef, the authors note the fat content as being the same between treatments and thus not responsible for flavor differences. They do suggest, however, the undesirable flavors were related to the fatty acid profile of beef with ALA and n-3 LCPUFA resulting in a greater likelihood of off-flavors and larger amounts of stearic acid in neutral lipids resulting in the most desirable flavor (Melton et al., 1982). However, as much of the U.S. sensory research regarding the acceptability of grass/forage-fed beef was conducted in the 1970s and 80s (Crouse et al., 1984; Hedrick et al., 1983; Melton et al., 1982; Reagan et al., 1977; Schroeder et al., 1980) more current research is needed to determine if U.S. acceptance of the flavor quality of grass/forage-fed beef has evolved. Most recently, trained sensory panelists found beef from grass-finished cattle to lack beef flavor and to present with greater off-flavor than beef from grain-finished cattle (Duckett et al., 2013).

5. Conclusions

In the U.S., comparable lean beef cuts from cattle consuming mostly grass/forage appear to be lower in fat than those from grain-finished beef, largely at the expense of MUFA. Both U.S. grass/forage-fed beef and grain-finished beef contribute omega-3 fatty acids to the diet predominately as ALA. It appears that lean beef from either feeding regime can make a modest contribution to n-3 LCPUFA intake goals while contributing a limited amount of total fat to the diet. Evidence from a limited number of U.S. studies suggests that beef from both grass/forage-fed or finished and grain-finished cattle contributes a wide variety of important nutrients to the U.S. diet and consumption of either can be compatible with efforts to improve the cardiovascular health of Americans. More U.S. studies are needed to better define the intake of various nutrients to be obtained in a larger variety of cuts from grass/forage-fed beef. Such information will be useful for nutrition professionals counseling clients, consumers making purchasing decisions, and improving the accuracy of nutrient databases.

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