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Alternative Beef Production Systems: Issues and Implications

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Abstract

Beef markets in the United States are undergoing rapid change as alternative production systems and technologies evolve in response to consumer demands and compete with conventional grain-fed beef production. Beef produced through distinguishable systems results in products with different marketable attributes that may attract price premiums. Beef produced through each system is often associated with claims relating to input and other resource use, land allocation, environmental impacts, greenhouse gas emissions (GHG), animal welfare, the use (or not) of specific animal health products, slaughter/processing infrastructure and efficiencies, and providing continuous supplies of safe products for both domestic and international markets. Markets are rapidly changing as consumers demand various combinations of these attributes in their beef products and as science and consumer knowledge converge. We explore the market outlook implications of these changes by examining the specific production technologies behind alternative production systems and products.

Keywords: beef production, grass-fed, grass-finished, organic, conventional, alternative, niche, cattle, resource use

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Introduction

As agriculture evolves, it faces new sets of challenges and opportunities as consumers demand products with increasing arrays of attributes, as producers adapt to meet consumer demands for alternatives, and as policymakers seek solutions to the food and resource challenges of an increasing global population. Food product characteristics stem from variations in production systems, each of which requires a set of unique resources and generates tradeoffs in resource use, greenhouse gas emissions (GHG), animal welfare, food safety and quality, the use of specific animal health products in production, and—important to sustainability—costs.

These tradeoffs are particularly evident in livestock sectors. While consumer perceptions of each system motivate demand for products with attributes for which they are willing to pay premiums in the market place, the accuracy of these perceptions is not always current (e.g., Kijlstra et al., 2009; Siegford et al., 2008). Markets are rapidly changing as consumers demand various combinations of attributes in beef products and as science informs the substance of some of the claims made for these attributes and consumer perceptions of them. We explored the market outlook implications of these changes by examining specific production systems—natural, certified organic, grass-finished, and conventionally produced beef—and the products derived from each. Although most of these issues are relevant for all livestock species, we focused on U.S. cattle¹ markets and markets for beef products resulting from them. We summarized results from the limited number of studies that compare salient characteristics and/or net costs of/or returns to beef production systems, the attributes/characteristics of products from each system, and estimates of premiums consumers may be willing to pay.

Beef marketed in the United States can be broadly classified as having been produced through either a conventional (or traditional) grain-fed or an alternative system. U.S. demand for beef finished without grains, antibiotics, artificial hormones, or other conventional inputs has motivated changes in beef production and technologies that support small but rapidly expanding markets for beef produced via alternative production systems. As a result, producers, consumers, and other beef advocates from each production system often attempt to enhance distinctions between products from alternative versus conventional beef production systems. Proponents often make nutritional, environmental, quality, human health, and/or animal welfare advantage claims to distinguish their products from those of other systems and offer defining criteria as justification to shift consumer preferences. Despite generally declining per capita consumption of beef and red meats, beef from alternative production systems—natural, organic² (grain-fed or otherwise), and grass/forage-fed (including cattle finished on grasses/forages to a specific quality standard)—accounts for about 3 percent of the U.S. beef market and has grown about 20 percent per year in recent years, according to the Irish Food Board/Bord Bia (FeedInfo News Service, 2010).

Although similar in many respects, conventional and alternative beef production systems and their products offer unique characteristics, which have implications for the economic and environmental sustainability of each system. Increasingly, beef consumers with preferences for specific

¹“Cattle” is a generic term that can refer to all categories of bulls, steers, cows, heifers, and/or calves. A bull is a sexually mature, uncastrated male, generally employed for breeding purposes. A steer is a bovine male castrated before reaching sexual maturity. A cow is a mature female, usually having had at least one calf. A heifer is a bovine female that has not given birth to a calf. Feeder cattle are usually yearling (between 1 and 2 years old) steers and/or heifers ready to be finished for market. Finishing is the stage of production prior to slaughter in which an animal’s weight is increased to produce desirable carcass characteristics. These and other definitions can be found at: <http://www.ers.usda.gov/topics/animal-products/animal-production-marketing-issues/glossary.aspx>.

²For our purposes, “organic” refers to USDA certified organic, which is regulated and certified by USDA as a product meeting specific requirements. “Natural” is a labeling convention and marketing claim that can vary significantly with company-specific labeling standards but is not currently Government certified.

attributes are willing to pay premiums for products with the attributes each consumer prefers (McCluskey et al., 2005; Brewer and Calkins, 2003; Umberger et al., 2009). However, scientific research does not always support the validity of these perceived differences in product attributes (e.g., Faucitano et al., 2008; Duckett et al., 1993). Are there advantages to producing beef through one system over another, and how different are the products—using objective measures? What are the environmental, cost, and market implications for increasing finished beef production through forage-based systems? Definitive conclusions are difficult to draw, in some cases, but a small but growing body of scientific literature provides insights into the tradeoffs in resource use, etc., that arise from producers utilizing conventional versus alternative production systems.

Comparing Beef Production Systems

Historically, cattle production for beef or dairy in the United States has been a forage-based industry, and virtually all beef production systems continue to use significant quantities of forages or other roughages as the primary feed source. Over time, and as land became more intensively used to produce both crops and livestock (more animals on less pasture land as more land was converted to cropland and other uses), the introduction of grain into feed rations shortened the beef production period and resulted in a more tender meat product containing more intramuscular fat, or “marbling.” Land-use patterns shifted away from forage production to grain production for both human food and animal feed, increasing efficiencies in terms of reduced costs per unit of product. Large concentrated cattle-feeding operations evolved as a way to capture economies of size and other production and supply chain efficiencies that reduced cattle and beef production costs.

While practices vary widely across specific beef production systems, most cattle are typically born and raised on range or pasture land for the majority of their lives. Cattle in the United States, whether finished with grain or forages, spend at least half of their lives on pasture of some sort (fig. 1). A pasture phase is virtually universal, largely because cattle, as ruminants,³ have the ability to convert cellulose (a significant component of all plants) into meat. Other than nursing, virtually all of the animal’s initial weight gain comes from some form of forage, with roughages—pasture, hay, silage, or alternative forages—accounting for almost the entire ration fed to a beef calf prior to placement in a feedlot. Roughages are also necessary in feedlot rations to maintain healthy digestive systems in grain-fed cattle.

Roughly 80 percent of commercial beef production (the average ratio of steer and heifer slaughter to total slaughter adjusted for differences in carcass weights, 2005-11) is “fed beef” and comes from cattle—mostly steers and heifers—fed grain for finishing. Between 15 and 20 percent of cattle on feed are fed in feedlots with less than 1,000-head capacity. Beef from grain-fed cattle often reaches the highest quality categories of (in descending order) Prime, Choice, and Select. The remaining 20 percent of commercial production is “nonfed beef” and comes from cattle that are generally not fed feedlot rations, such as dairy cows, beef cows, dairy bulls, beef bulls, and other animals. Nonfed beef seldom achieves even the Select grade because it lacks marbling or comes from cattle that are too old to be categorized in the top three grades. Higher quality grass-finished beef—also “nonfed beef”—can be graded as Choice or Select. Similarly, while culled dairy cows are considered nonfed beef, they often have been fed rations containing grains to enhance milk production during most of their lives and, while too old to be graded as Prime, Choice, or Select, they can still contain significant fat and marbling.

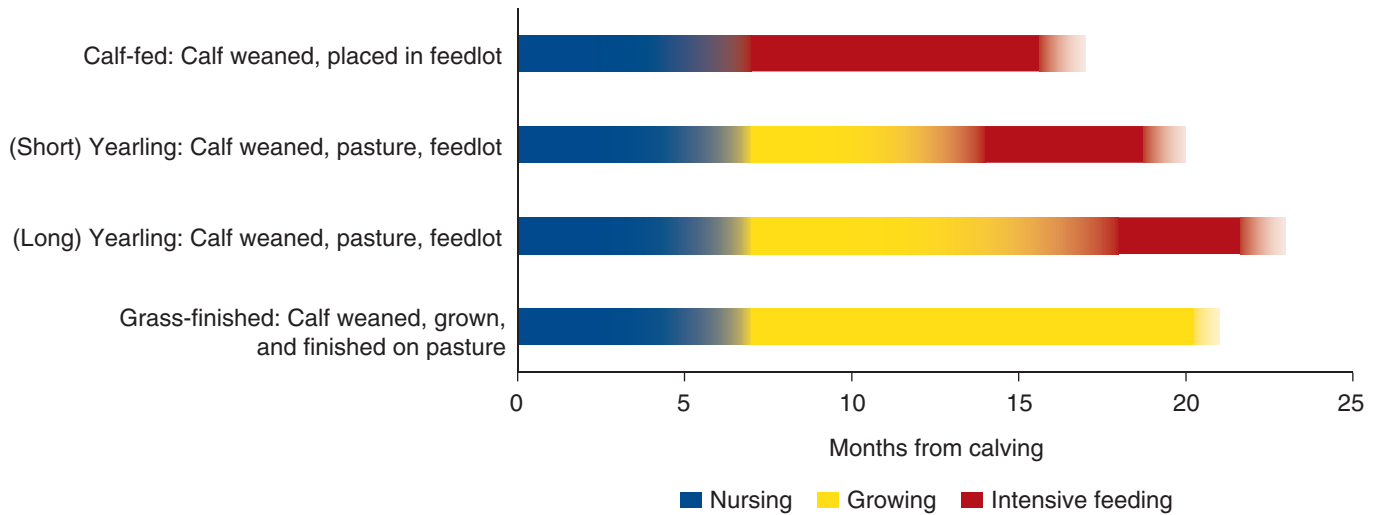
Conventional Beef Production

Conventional beef production is defined for our purposes as traditional feedlot production of grain-fed beef in which steers and heifers receive feed rations consisting largely of grain-based energy and protein to achieve maximum weight gains at the lowest possible cost while in the feedlot. In

³Ruminants are animals with multiple stomach compartments, one of which is the rumen, where cellulose is fermented into simpler sugars. Cattle, sheep, goats, deer, elk, and bison are all ruminants. Hogs and horses have simple stomachs with only one compartment.

Figure 1

Production-cycle timelines for grass-finished versus conventional grain-fed beef production¹



Source: USDA, Economic Research Service.

¹Veal is excluded from this report and this figure. Veal accounts for half of 1 percent of total beef and veal and is generally produced while the veal calf is in the "nursing" range, sometimes as young as 2 weeks of age. Further, Holstein steers and some Holstein heifers constitute a small portion of total cattle fed, but many are finished in programs that place them on feed (generally a milk- or milk-replacer-based ration) soon after birth, moving to more conventional feed rations until slaughter at weights comparable with fed cattle. These cattle are also not explicitly represented in the figure. As a result of the differences in feeding approaches, and a high degree of biological variability in cattle, actual demarcations between production phases vary considerably. For example, calves are weaned at ages extending from 5 months to 9 months of age, and feeding periods may differ by several months.

conventional beef production, producers may—not all do—use antibiotics and growth promotants to enhance production through gains in feed efficiency and feed conversion. Feed costs are, thus, reduced and animal health is improved partly by reducing acidosis, which reduces the number of livers (or cattle) condemned as unfit for human consumption. Conventional production practices can vary widely. For example, animals may or may not be fed or implanted with growth promoting products, and commercial and/or natural fertilizers may or may not be used to produce the grain and forages fed to animals.

In conventional beef production, virtually all of the weight gained prior to placement in the feedlot comes from some form of forage (see fig. 1 and table 1). Cattle may enter the feedlot directly after weaning (calf-fed) or be backgrounded (grown) in dry lots or on pasture (“stockered”) prior to placement in feedlots as short- (younger) or long- (older, larger) yearlings. Cattle backgrounded in dry lots are fed a growing ration composed of energy, protein, and forages. Cattle on pasture or forage generally gain between 0.75 and 2.50 pounds per day, depending on the quality of the forage (and regardless of production system). Dairy calves may spend some time on milk-replacer and calf rations before either being slaughtered for veal or placed into more conventional beef production systems where calves are grown on pasture or harvested forages before being placed in feedlots. Generally, a fed steer at slaughter will have entered the feedlot weighing 600-900 pounds and will reach a typical slaughter weight of 1,200-1,500 pounds; fed heifers generally weigh 100-200 pounds less than steers when slaughtered.

Table 1

Summary of studies comparing conventional beef production with alternative production systems¹

Study	Number of head in study treatment	Slaughter weight (pounds/head)	Total days	Carcass weight (pounds/head)	Marbling score ⁷	Break-even price (\$/cwt)	Profits (\$/head)
Jordan et al. (2002) compares three conventional finishing systems:							
Calf-fed ²	1,257	1,234 ^s	182 ^{nt}	777 ^s	497 ^{nt}	68.10 ^{nt}	-23.18 ^{nt}
Fast gain on pasture (1.54 pounds/day), conventionally finished	212	1,360 ^s	387 ^{nt}	858 ^s	555 ^{nt}	66.00 ^{nt}	21.00 ^{nt}
Slow gain on pasture (0.42 pounds/day), conventionally finished	160	1,254 ^s	450 ^{nt}	790 ^s	531 ^{nt}	69.21 ^{nt}	-20.66 ^{nt}
Bennett et al. (1995) compares conventional and forage finished (natural) systems:							
Forage-finished ³	156	1,115.5	218	617	311		
Conventionally finished ³	152	1,234.6	176	763	367		
Fernandez and Woodward (1999) and Woodward and Fernandez (1999) compares conventional and "organic" systems:							
Conventionally fed ^{4,5}	12	1,273.5 ^s	163.62 ^s	790 ^s		61.55 ^{nt}	
Organic fed ^{4,5}	40	1,182.3 ^s	225.81 ^s	728 ^s		75.42 ^{nt}	
Lacy et al. (2011) compares conventional and natural (forage finished) systems:							
Natural ⁶		1,154 ^s	432 ^{s, 6}	703 ^s	81.9 ^{nt, 8}	91.47 ^s	-16.72 ^s
Conventional ⁶		1,198 ^s	414 ^{s, 6}	736 ^s	48.1 ^{nt, 8}	83.95 ^s	70.12 ^s

¹Column and row heading terminology is consistent with each source study. "Total days" generally commence at weaning or purchase. "Conventionally finished," "conventionally fed," and "conventional" refer to the most common beef production system in which cattle are fattened for market on grain-containing rations in feedlots at the lowest possible cost while in the feedlot and may be implanted with hormones and/or administered antibiotics at subtherapeutic levels. Prices and costs within each study are consistent and comparable, but comparisons across studies will not account for differences in real or relative prices across study years or treatment details across studies.

²"Calf-fed" means calves were placed on feed shortly after weaning.

³Average of 2 years. "Forage-finished" and "natural" means cattle were fed forages until slaughtered.

⁴Some values (e.g., break-even values) were calculated from results in table 5 from Fernandez and Woodward (1999). Veterinary costs were the only costs that were not significantly different between treatments.

⁵"Organic fed" means that this study preceded the establishment of organic certification for beef, but cattle were fed according to protocols largely consistent with organic beef production standards that eventually were established.

⁶Total days = birth to slaughter (Lacy et al., 2011).

⁷Marbling: 400 = slight and 500 = small (Hale et al., 2010).

⁸In Lacy et al. (2011), value is percent grading Choice or better. Differences in percent grading Choice and percent grading Prime were statistically significantly different, but the combination of Choice or better (Choice + Prime) was not tested.

cwt=Hundredweight.

Statistical indicators: s = statistically significantly different at P<.05; m = statistically significantly different at .05<m<.10; n = no statistically significant difference; nt = not tested.

Feedlot rations are carefully formulated to maximize growth rates for a concentrated time at minimum cost. In the feedlot, cattle will be on feed for 120-240 days and gain an average of 2.5-4 pounds per day. Each animal will consume 4,000-4,300 pounds of total feed on an "as-fed" basis⁴ while in a feedlot. Depending on the feeding stage and relative feed prices, feedlot rations will consist of about 80-85 percent grain (usually corn), distillers' grains, and/or other sources of starch/energy, and 10-15 percent hay, silage, or other forage. The remaining share of the ration will include some protein source like soybean or cottonseed meal, sometimes in conjunction with urea, which cattle can efficiently convert to protein. While in feedlots, cattle will convert 5-7 pounds of total feed (dry-matter basis, or 6-10 pounds on an as-fed basis) to 1 pound of gain (consisting of beef, bone, fat, organs, hide, other byproducts, and waste).

⁴Feed analyzed on an "as-fed" basis contains water versus a "dry-matter" basis whereby the water has been removed from the feed before weighing.

Increased feeding of ethanol coproducts like distillers' grains and corn gluten feed has somewhat altered what is considered a "typical" ration because coproducts now can constitute 20-50 percent of the ration. The energy content of ethanol coproducts is on par with other energy sources (grains), and protein content is intermediate between energy-rich grains, which contain about 12 percent protein, and protein feeds like soybean meal, which contain over 40 percent protein. Cattle can be fed a wide variety of other byproducts from food manufacturing (e.g., cookie crumbs, sugar beet tops, and orange pulp) to reduce feeding costs.

Beef cows are likely to have eaten forages all their lives. Recent surveys indicate that when pasture forages did not provide all the nutrients a cow needs, 75 percent of beef cow operations fed some supplemental protein during the year, and those that did averaged 173 days per operation (157 days per animal) (USDA/APHIS, 2010). Just over half of operations fed energy supplements during the year, and 70 percent of those operations fed energy supplements for 3 months or longer (USDA/APHIS, 2010). Beef cows will weigh about 1,100 pounds when culled (removed from the breeding herd) and will produce a carcass (dress) weighing around 50-55 percent of its liveweight. Beef also is produced from culled bulls, which may be fed some grain, but primarily for maintenance and body condition for breeding rather than for beef production. Dairy cattle also consume large quantities of grain, primarily for milk production and cow maintenance. Dairy cow slaughter averages around 47 percent of total commercial cow slaughter. Dairy cows are generally heavier than beef cows when culled and as dressed carcasses.

Organic Beef Production

According to USDA's National Organic Program standards (<http://www.ams.usda.gov/AMSV1.0/nop>), certain criteria must be met for any food to be certified USDA organic.⁵ These criteria greatly reduce variations in production technologies available to beef producers; however, organic certification affords an opportunity to receive a higher premium for the product, as is also often the case with "natural" and grass-fed beef. Producers (and processors) must first be "certified organic" by USDA as having met, at minimum, the following criteria for animal production:

- Animals for slaughter must be raised under organic management from the last third of gestation.
- Animals must not be given antibiotics or growth hormones (sick/injured animals must be treated but are removed from the National Organic Program).
- Grain and forage fed to animals must be 100 percent organic (not treated with pesticides, synthetic/bioengineered fertilizers, sewage sludge, or ionizing radiation for at least 3 years prior to harvest).
- At least 30 percent of the ruminant animal's forage needs must be met through pasture during the grazing season (grain-finished beef cattle are excluded from this requirement during the last 20 percent, or 120 days, of their lives, whichever is shorter).
- Processors of organic meat also must be certified.

⁵Information on organic production standards and regulations may also be found at <http://www.nal.usda.gov/afsic/pubs/ofp/ofp.shtml>.

Grass-Fed Beef Production

As most cattle consume forages nearly all their lives, a distinction must be made between grass-fed animals and grass-finished animals. Grass-finished cattle have grazed only on grass, pasture land, or other forages and, most importantly, have been fattened only on grass or forages to achieve adequate levels of finish to carcasses within an economically feasible time prior to slaughter. Finishing cattle on grass or forages alone requires large quantities of high-quality forages and strong operator-management skills. Otherwise, grass-fed beef is not substantially different from beef produced from culled cattle or beef imported for processing in that it generally lacks sufficient fat to reach an acceptable quality grade level (equivalent to USDA Select, Choice, or Prime grades).

The type and quality of forage fed to cattle affects animal weight gain and carcass characteristics. To increase an animal's weight solely on forage, the animal must have year-round access to high-quality forage. Providing sufficient high-quality forages throughout the year is physically difficult and costly in much of the United States because of the seasonal growth habits and nutrient contents of most forages. Further, cold temperatures increase energy requirements necessary to maintain an animal's normal body functions, which must be met before growth and fat deposition take place. Alternatively, during warmer temperatures, reduced feed intake presents a challenge to achieving sufficient quality while forage-finishing cattle.

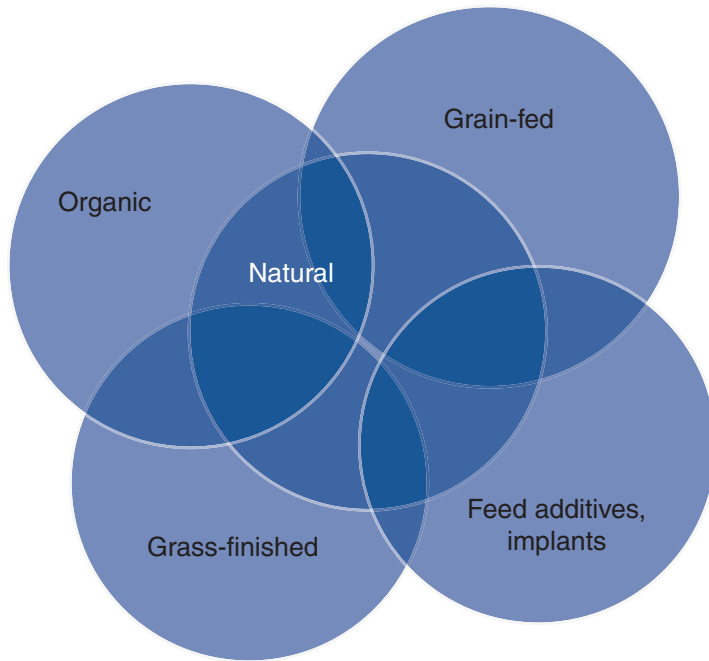
Producers who market high-quality forage-finished beef have reduced variances that may occur in the product as a result of differences in genetics, forage type and quality, and/or other management practices. They accomplish this through careful attention to grazing management and often by using breeds with selected characteristics or genetics. Faucitano et al. (2008) found that, when fed to the same level of finish (8 millimeters of backfat), there was no statistically significant difference in tenderness scores between beef from cattle fed grass and silage and those fed grain. Another study reported, however, that feeding grain to cattle reduced the length of the feeding period by 21 percent (Berthiaume et al., 2006), which generally lowers per-unit production costs (see table 1).

Comparing Production Systems

Beef produced and marketed with different claims may have been raised in a system that shares some production characteristics and marketable attributes with another system (fig. 2). For example, grass-finished beef may qualify as "natural" or "certified organic" as a part of a more comprehensive production system; however, grass-finished beef is not by default "natural" or "certified organic" and vice versa. Beef from an animal may be marketed as "grass/forage-fed," for example, but if given antibiotics or implanted with growth promotants, it would be disqualified from many specific "natural" beef programs and certainly from being labeled as organic. Likewise, beef from cattle raised on pastures treated with synthetic fertilizers would not qualify as organic, and beef from cattle raised naturally or organically may not have been exclusively fed forages. Grass-only production, however, can be tailored to use minimal or no antibiotics or hormones, thus reducing the potential for

Figure 2

Some beef production technologies overlap, but some are mutually exclusive



residues in meat or organs—which is virtually zero if proper drug label directions are followed—and, when coupled with other distinguishing criteria, can lead to grass-finished products amenable to natural or certified organic beef production systems.

These production systems have existed for many years, so research comparing production systems is dated, and, in some cases, precedes current designations (e.g., “organic-fed” in table 1 preceded “organic beef”). Most alternative production systems differ from conventional systems only in the final finishing phase. Natural, certified organic, and grass-finished beef production systems often emphasize feeding forages to animals or grazing pastures to achieve weight gains and a level of finish⁶ acceptable to the market. Some natural and certified organic beef is grain-fed. Only about two-thirds of organic beef is grain-fed because of the high costs of organic feeds compared with conventionally grown feeds (Roberts et al., 2007). Roberts et al. (2007) observed that premiums for organic feeds were 57 percent above conventional feeds. In some years, organic grains may only carry premiums of 25 percent or so, although premiums are generally much higher, sometimes more than 100 percent higher, which accounts for some of the difference in observed costs for organic versus conventionally fed beef (see table 1).

Morley et al. (2011) found a statistically significant difference in the number of days fed between conventionally fed (162 days) and cattle fed without antibiotics (212 days) but no differences in beginning or ending weights. Acevedo et al. (2006) demonstrated the profit advantages of shortened production periods associated with grain feeding and the impact of varying premiums on net present values from each of their simulated production technologies. Conventional grain feeding was 52 percent more profitable than natural grain feeding and 5.6 times more profitable than organic grain

⁶“Finish” refers to the combination of frame, body condition, and fat (external, internal, and marbling) of an animal at the time it is ready to be slaughtered for beef.

feeding, largely as a result of the high cost of organic grain. Grain feeding was more profitable than grass feeding for both organic and natural production, and natural grass feeding was the least profitable technology by a wide margin, largely as a result of the small premiums associated with its products.

In their meta-analysis of efficiency gains from pharmaceutical technologies, Wileman et al. (2009) analyzed results from 51 studies of conventional, organic, and natural beef production with untreated control groups, finding significant efficiency gains and cost reductions from the use of pharmaceuticals (mainly antibiotics and implants) in beef production. Their analysis indicated efficiency gains of 17 percent in average daily gain (ADG) and 9 percent in weight-gain-to-feed ratios (G:F) from a single hormone implant. Further results indicated a 53-percent reduction in morbidity and a 27-percent reduction in mortality from metaphylaxis (whole-group treatment with pharmaceuticals) upon the arrival of cattle at the feedlot. In their study, feeding tylosin (an antibiotic) to feedlot cattle reduced risks of liver abscesses by 8 percent but no consistent advantage over control groups with respect to ADG, G:F, or feed intake (dry-matter basis: DMI). These efficiency gains and other factors (e.g., organically grown grains cost more than conventionally grown grains) resulted in simulated cost advantages of conventionally produced cattle over others of \$77/head (over nonimplanted control groups) and \$349/head (over organically fed cattle). They also found that a 10-percent increase in the price of organic feed increased costs by \$54/head.

Alternative Beef Products and Labeling

Natural beef—The USDA definition of natural beef refers only to the product itself and not specific animal production practices. For beef to be labeled as “natural,” the product must contain no artificial ingredients or added color and must be minimally processed.⁷ USDA does not require any certification standards or regulations on how the animal should be raised.⁸ As a result, natural beef can be produced by conventional or other grain-feeding practices. Additional labels that convey use of a “natural” production system are largely defined and regulated by the companies or organizations that label the product as “natural.” However, naturally raised beef, produced according to the standards of a natural beef production program, generally means that the animal has not been implanted with artificial hormones or fed antibiotics, ionophores,⁹ or other additives. The production program of an individual or company, however, may qualify for various quality or process merits verified by USDA’s Agricultural Marketing Service (AMS) Process Verified Program, which allows the producer to qualify for marketing claims that may appear on labels (see <http://www.ams.usda.gov/AMSV1.0/processverified>).

Organic beef—Marketing organic beef was hampered until 1999 when USDA approved a provisional label for organic meat and poultry (Greene, 2001). Meat and poultry fall under USDA jurisdiction, while organic crops fall under U.S. Food and Drug Administration (FDA) jurisdiction and were allowed to be labeled “organic” much earlier than meat. As a result, organic beef production prior to 1999 was often labeled as “natural,” “organic fed” (see table 1), or other designations.

Grass-fed beef—As is the case with “natural” beef, production practices of grass-finished beef depend largely on either the individual producer’s

⁷“Minimal processing may include: (a) those traditional processes used to make food edible or to preserve it or to make it safe for human consumption, e.g., smoking, roasting, freezing, drying, and fermenting, or (b) those physical processes which do not fundamentally alter the raw product and/or which only separate a whole, intact food into component parts, e.g., grinding meat...” (USDA/FSIS, 2005). See FSIS Policy Memo 055, August 2005, Food Standards Labeling Policy Book (http://www.fsis.usda.gov/oppde/larc/policies/labeling_policy_book_082005.pdf).

⁸Note that “On September 14, 2009, FSIS issued an Advance Notice of Proposed Rulemaking to assist the Agency in defining the conditions under which it will permit the voluntary claim “natural” to be used in the labeling of meat and poultry products (<http://www.fsis.usda.gov/oppde/rdad/frpubs/2006-0040A.pdf>).”

⁹Ionophores are molecules widely used in livestock feeding that have antimicrobial properties as a result of their ability to transport ions across cell membranes (e.g., Monensin and Lasalocid).

standard practices or those defined and regulated by the companies that label the product “grass-fed” or “grass-finished.” Beef from grass-fed ruminants, however, can be labeled with a “grass (forage) fed” marketing claim through the AMS Process Verified Program if fed according to USDA standards. Under this verification standard, grass or forage must be the exclusive feed source throughout the lifetime of the ruminant animal except for milk consumed prior to weaning. The animal cannot be fed grain or any grain byproduct prior to marketing and must have continuous access to pasture during the growing season. However, silage is an accepted feed that can consist of relatively large portions of grain. For example, corn silage, which averages 10-20 percent grain, can consist of up to a third or more grain (Bates, 1998), which blurs the distinction between grain-fed and forage-fed.

Slaughter and Processing Issues: “Locally” Sourced Products¹⁰

Because alternative cattle production systems are often smaller, local, and dispersed operations, increasing consumer demand for alternatively produced beef has implications for animal slaughter and processing. While most conventionally produced beef is processed in large plants, beef produced from alternative systems often is processed at smaller, local facilities. Locally sourced beef products can be defined by region, company, marketing channel, and by consumer definitions, and can vary by scale of production, supply chain, and marketing outlet. “Local” can imply beef from a producer selling a portion of an animal to a neighbor to much more complex arrangements like a set of producers raising animals in a designated production system, for a local meat brand, marketed fresh on a year-round basis to restaurants, retailers, and other food service. Limitations in slaughter and processing locally sourced beef are often cited—particularly by producers—as one of the key barriers to the marketing and expansion of alternatively produced beef.

Both consolidation and attrition have occurred in the livestock slaughter sector over the last decade, and processing infrastructure is such that most livestock in the United States are processed at a relatively small number of large-volume federally inspected (FI) plants. During the last 10 years, 55 percent of cattle were slaughtered in plants that process 1 million or more head per year, just under 44 percent were slaughtered in plants that process 10,000 to fewer than 1 million head per year, and just over 1 percent were slaughtered in plants that process fewer than 10,000 head per year (USDA/NASS, 2012). However, large plants with scale economies, even if conveniently located, are essentially unavailable to local meat producers due to mismatches in scale, services, and business models (Johnson et al., 2012).

Producers using alternative systems are not always able to provide larger lots of the uniformly sized animals preferred by larger processors, thus leaving them to rely on small-scale slaughter or processing facilities. Larger slaughter facilities also cite biosecurity issues (infectious disease transmission, traceability, etc.) for not accepting cattle from small-scale producers, who do not have the resources or organizational capacity to enforce particular standards (e.g., Crutchfield et al., 1997). Further, many larger plants that might otherwise consider working with small livestock producers find it financially infeasible to break carcasses down further than subprimal cuts. Large plants

¹⁰This section is paraphrased from Johnson et al., 2012.

that do retail cutting typically sell the product under their own label. If they were to process small batches of custom product, they would find it labor-intensive and a potential conflict of interest (Johnson et al., 2012).

Location issues also limit the viability of smaller processors. In 2009, USDA's Rural Development Agency identified areas in the United States where small livestock and poultry operations are concentrated and where there is a lack of small federally and/or State-inspected slaughter establishments in their vicinity, which can affect marketing and interstate commerce. For cattle, lack of small slaughter facilities in relation to large numbers of small farms is evident across central Texas and into Oklahoma, Arkansas, and Missouri; areas of the Southeast along the Appalachian Mountains; and numerous counties in the West (Arizona, Washington, Oregon) (USDA/FSIS, 2010). Even in areas with a number of small appropriate slaughter/processing facilities, these facilities may not be economically feasible due to a lack of consistent throughput of cattle. Growth in small-scale slaughter and processing facilities depends on whether producers in need of these services can provide enough throughput, for enough of the year, and pay a high enough fee for the services to make such facilities economically viable. Further, lack of slaughter facilities may not always be the limiting factor for local or alternative production; quality retail cutting may be a greater challenge in some areas for local marketers considering that retail cutting is more labor intensive and therefore more costly (Johnson et al., 2012) .

Alternative methods for slaughter and processing geared toward niche markets—such as local and regional market aggregators and mobile slaughter facilities—may help meet some of the need for increased slaughter and processing capacity in localized areas. In such systems, both processors and their customers can benefit from scale economies, particularly with regard to collection and sales of byproducts, as well as with efficiencies gained from using the same cutting methods for larger groups of carcasses. Further developments in structural innovations for slaughter and processing are necessary to enable the growth of alternative livestock producers marketing product to consumers in their region or community.

When Do Differences Matter?

As alternative beef production systems and products emerge, the attributes of each system—nutrition, resource and other input use, GHG emissions, animal welfare, processing and food safety/security concerns—have implications for both consumers and producers (fig. 3). The attributes of meat produced from each system fulfill specific consumer preferences resulting from deviations from conventional production practices. Differences in final beef products matter most to producers and consumers when there are measurable or perceptible differences for which consumers are willing to pay premiums. Among the beef products from each system, some attributes are readily distinguishable:

- Use of animal health products; and
- Taste, appearance, and nutritional profiles.

Conventional beef production has been criticized for the use of drugs and hormones (food safety and healthfulness), manure management (pollution), animal welfare (crowding), and grain feeding (resource use). Since most of these factors developed as cost-reducing measures, feeding costs will likely increase to the extent that these practices are eliminated under alternative beef production systems. Some costs may be offset by increased management skills specific to the alternative production system or new technologies.

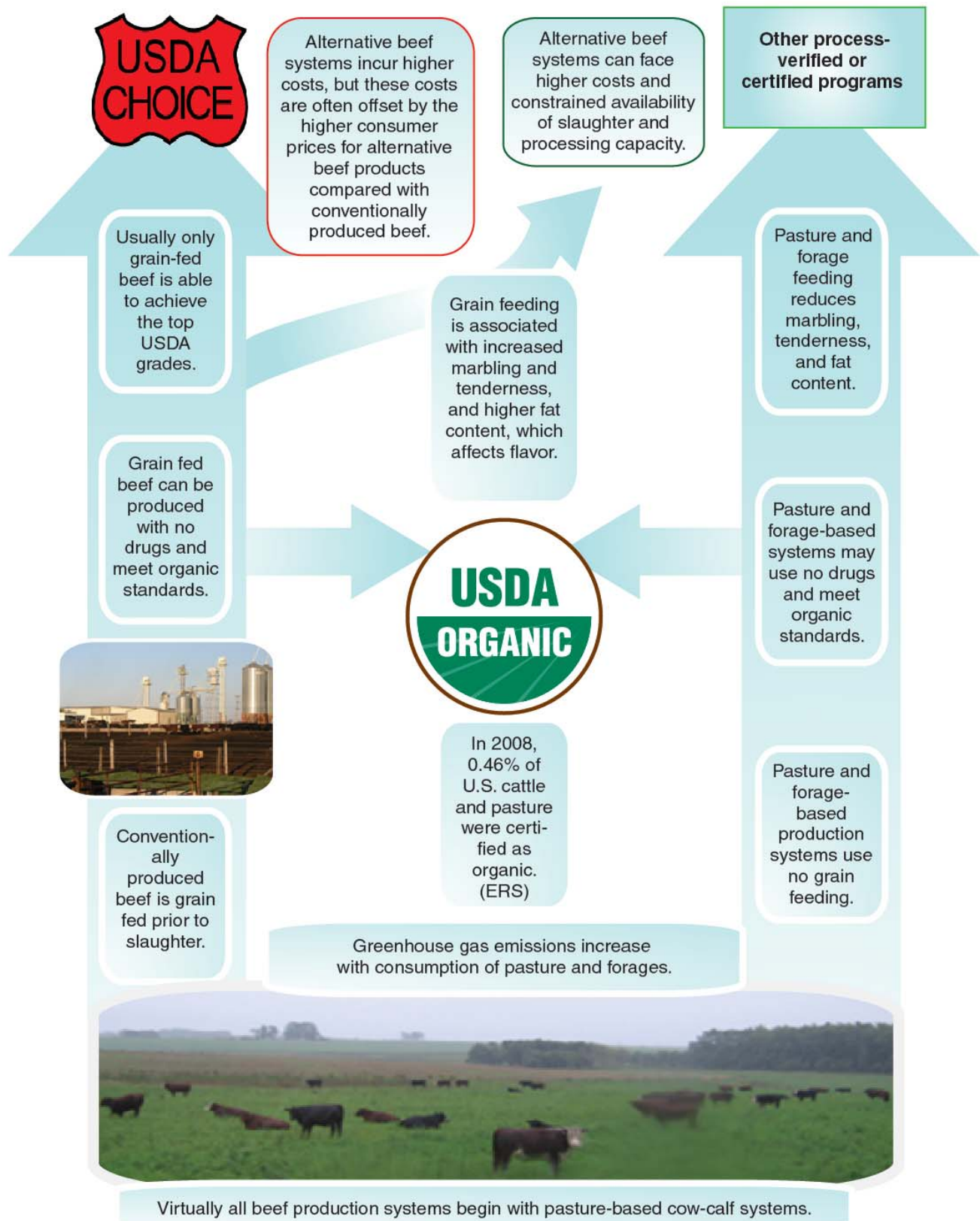
In some cases, science contributes information that helps assess specific differences where they exist in beef products (e.g., omega-3 fatty acid content, antibiotic free). Recent research addresses welfare issues, food safety, and nutrient profiles. In other cases, consumers who place greater value on less tangible bundles of characteristics (e.g., environmentally friendly, local) or on personal tastes can also satisfy their preferences through the array of products from the various production systems. Evidence suggests that consumers are willing to pay premiums over conventionally produced beef prices to obtain products consistent with their preferences (e.g., Abidoye et al., 2011; Springer et al., 2009; Umberger et al., 2009; Dutton et al., 2007; McCluskey et al., 2005; Sparling et al., 2002; Umberger et al., 2001). Each topic in what follows is worthy of a comprehensive treatment. To meet our objective of comparing production systems, however, we have focused on a brief discussion of the discernable perceptions between beef production systems, particularly for animal welfare, GHG emissions, and food safety.

Use of Animal Health Products¹¹

While an integral part of some alternative beef production systems, the use of animal health products is most often specific to conventional beef production. Cattle on pasture are generally administered fewer animal health products than cattle in feedlots. As a general rule at the cow-calf level, animal health products are used minimally. A survey done by USDA's Animal and Plant Health Inspection Service (APHIS) revealed that only 11.9 percent of calves over a 12 month period were implanted with growth promotants prior to or at weaning (USDA/APHIS, 2008).

¹¹Vaccines—excluded from the general dialogue on animal health products in the context of consumer preferences—are used in all cattle production systems to prevent diseases from viruses and some other disease-causing microorganisms. Vaccines are very different from other animal health products in that they leave no residues and, instead, build antibodies that fight viral and some other infections. A survey by USDA's Animal and Plant Health Inspection Service (USDA/APHIS, 2010) found that 69 percent of a representative sample of all U.S. cattle, including organically produced, were vaccinated against an array of disease-causing microbes, and in the Central United States—home to roughly half of U.S. cattle—91 percent of cattle were vaccinated for something. Vaccines also may be used to reduce prevalence of pre-slaughter foodborne pathogens (Dodd, 2010). Additionally, the appropriate use of antibiotics and other animal health products is encouraged in the most restrictive production systems, lest withholding them when their use is indicated becomes an animal welfare issue of a different sort.

Figure 3
Multiple beef production systems provide consumers with beef products that match their preferences



Sources: USDA, Economic Research Service. Photos: Monte Vandever and Kenneth H. Mathews, Jr.

The use of some compounds is virtually universal among large commercial feedlots. Some evidence suggests that their use may be declining over time (USDA/APHIS, 2000a and b). In the United States, antibiotics are often used in feedlots to treat or prevent diseases and to promote growth, although, ionophores and artificial growth promotants are more often used to promote growth and feed efficiency, reducing costs. Low-level antibiotic use prevents liver abscesses and subsequent condemnation caused by the effects of lactic acidosis produced from digesting high-starch (grain) rations. The recent increased availability of wet and dried distillers' grains, corn gluten feed, and other coproducts from corn sweetener/ethanol production may provide an economic solution to the high starch-related liver disease issues through their fiber content, since fiber (or cellulose) reduces ruminal organic acid production (Erickson et al., 2007). The inclusion of coproducts could reduce the need to include low levels of antibiotics in feed.

Very little beef in the United States is actually adulterated with drug residues because withdrawal periods are such that, when followed by producers, any traces of the drugs are eliminated before the animals are slaughtered. Antibiotics, artificial hormones, and other drugs for growth promotion, however, have been detected as residues in meat in some cases. In 2007, the national average for residue violations in cattle at all slaughter plants was two violations per plant (USDA, Office of Inspector General, 2010). Surveillance and monitoring over the same period indicated that 4 percent of cattle violations were in beef cattle and more than 90 percent were in dairy cattle. In 2007, most drug-adulterated beef in the United States came from a relatively small pool of dairy cattle, and 94 percent of those were attributable to repeat violators (USDA, Office of Inspector General, 2010).

Secondary factors may play a role in how antibiotics are introduced into the environment, including water supplies, as manure and livestock litter are applied to cropland and other lands (Chee-Sanford et al., 2009). Some drug residues excreted in manure have relatively long half-lives, increasing their potential for contaminating water, altering the composition and diversity of indigenous soil microbe communities, and potentially contributing to antibiotic resistance in microbes (e.g., Wang and Yates, 2008; Wang et al., 2006).

Although implicit justifications vary, a number of studies have demonstrated that consumers are willing to pay premiums for beef products produced without antibiotics, artificial hormones, or other chemicals (Abidoye et al., 2011; Springer et al., 2009; Umbarger et al., 2007; Dutton et al., 2007). Abidoye et al. (2011) found consumers willing to pay a premium of \$0.76 per pound for beef produced without hormones. Dutton et al. (2007) found consumers in three metropolitan areas (Oklahoma City, Tulsa, and Denver) paid average premiums of \$1.45 per pound for ground products and \$5.87 per pound for steak products labeled as "special" (i.e., no antibiotics, no hormones, all natural). Umbarger et al. (2007) reported that, "[w]hen consumers were presented with information indicating that the steak was produced without the use of hormones or antibiotics, they were 17.1 percent more likely to purchase GRASS [raised on forages without antibiotics or hormones] beef." In a survey of companies that purchased and marketed naturally produced cattle, Springer et al. (2009) found that 84 percent of the companies were willing to pay a premium of \$5.95 per hundredweight for

cattle that had never received antibiotics, ionophores, hormones, or animal byproducts.

Environment, Taste, Appearance, and Nutritional Profiles

Differences in taste, appearance, and nutritional profiles are largely a result of grain feeding versus grass/forage finishing systems, which make for a difficult comparison among production types. For example, grain feeding and grass/forage finishing systems also have implications for resource use—land use and water allocations¹²—that support pasture-based or grain-based production, as well as for animal welfare, and food safety and security. Scientists continue to focus on the differences in beef production systems and the science behind the use of land resources and grain feeding, as they relate to greenhouse gas (GHG) emissions and efficient food production. To understand the logic behind the premiums that consumers are willing to pay for taste, appearance, and nutritional preferences, it is useful to have some understanding of how well science meshes with perceptions.

Land resources—U.S. land resources are extensive and include private lands (59 percent of all land) and publicly owned Federal lands (29 percent) (Nickerson et al., 2011). In 2007, about 777 million acres of the total 2,264 million acres of U.S. land was grazed land (Nickerson et al., 2011), including roughly 200 million acres of grazed lands owned by various Federal entities (U.S. Department of the Interior, Bureau of Land Management, 1992). Much of this area is capable of little other agriculture than forage production, and, as such, opportunities for tradeoffs between crops and forages are somewhat limited. The abundance of forage-producing land forms the basis for the extensive dependence of all U.S. beef production systems on forages for at least a portion of needed nutrients at some point in their production cycles. With this in mind, some tradeoffs must take place among the various beef production systems in the context of GHG emissions and feeding grain versus forage-based production.

Greenhouse gas (GHG) emissions—In 2010, agriculture contributed 6.3 percent of U.S. anthropogenic¹³ GHG emissions—carbon dioxide, methane, and nitrous oxide (EPA, 2012)—with food production a largely unavoidable source. GHG generation occurs in nature as well as being “anthropogenic.” As the United States was settled, anthropogenic GHG sources replaced or added to natural sources as domestic species replaced native species for food production, largely to meet the demands of a growing U.S. and world population. Food crops replaced native plants, and cattle supplanted bison and other natural grazing animals (deer, antelope, and elk) as sources of meat. Virtually no information exists that quantifies the net change in GHG generation from historically natural GHG emissions by wild meat-producing natural sources to the domesticated anthropogenic sources that have superseded them. The emergence of domestic ruminants, especially cattle, presumes that they tasted better, were easier to handle, or were more efficient in some input-output sense than wild, native ruminants at converting vast areas of vegetation into high-quality protein for a burgeoning human population. Further, while U.S. anthropogenic emissions might be lower if there were generally less meat production/consumption, efficiency gains have occurred in both dairy

¹²Although there are occasionally discussions that refer to the use of water in the production of crops fed to livestock, we are not aware of any studies that compare water use across production technologies.

¹³Anthropogenic means attributed to human activities.

(Capper et al., 2009) and beef production (Capper, 2011 and 2010) that have further reduced environmental impacts per unit of meat output.

Cattle produce GHGs as the cellulose from plant materials ferments in their rumens, which allows them to convert a relatively large area of marginal unarable land, cropland largely devoted to pasture production, and crop residue into beef. In 2005, livestock were estimated to be responsible for 54 percent of GHG emissions from U.S. agriculture (USDA/Office of the Chief Economist). In Australia, 70 percent of GHG emissions from agriculture, or 11 percent of the national total anthropogenic GHG emissions, was attributed to livestock production (Peters et al., 2010). The Food and Agriculture Organization (FAO) of the United Nations estimated livestock's contribution to total global anthropogenic GHG emissions at 18 percent (FAO, 2006).¹⁴ Most peer-reviewed estimates for anthropogenic GHG emissions from all livestock in various countries range from 3 to 11 percent of total anthropogenic GHG emissions, varying directly with dependence on natural forages and contribution of livestock to total agriculture (Pitesky et al., 2009; Peters et al., 2010). Conversely, grazing cattle also has been shown to reduce natural emissions of nitrous oxide—the GHG produced in greatest quantities on grazed lands (USDA/Office of the Chief Economist, 2008)—from semi-arid rangelands (Wolf et al., 2010).

Several factors appear to affect GHG emissions. Ruminant consumption of some types of forage produces more GHG emissions than from consumption of other forage species (Chavez et al., 2006). Several studies point out the reduced GHG emissions, especially of methane—the most potent GHG produced in the greatest quantities by ruminants (USDA/Office of Chief Economist, 2008)—from ruminant digestion of grain starches compared with consumption of forages (e.g., Pitesky et al., 2009; Johnson and Johnson, 1995; Pelletier et al., 2010; Peters et al., 2010.). Pelletier et al. (2010) compared two grain-fed systems and one forage system within the same boundary conditions. They found that “[i]mpacts [in the form of GHG emissions] per live-weight kg of beef produced were highest for pasture-finished beef for all impact categories and lowest for feedlot-finished beef...”

Grain production systems also need to be considered because they have a relative effect on grain-feeding systems and the implications for total GHG emissions, the effect of fertilizers and pesticides on water quality, biodiversity and the environment, and other issues. Synthetic chemicals used in conventional agriculture often are criticized for their persistence in the environment, residues on final products, and their effects on water quality. At the same time, fertilizers, pesticides, and other chemicals approved for use in organic agriculture are not always benign (Bahlai et al., 2010) and may require more applications (more GHG-emitting passes over the crop) than synthetic chemicals.

Research on the effects of manure management, differences in feeds, land management, and many other factors that affect GHG and beef production may provide opportunities for reducing the environmental impact per unit of beef from all beef production systems (e.g., Capper, 2011 and 2010). As differences in GHG emissions between production technologies become better established scientifically, consumers will be better able to more accurately ascribe monetary values to their preferences for these characteristics.

¹⁴The FAO estimate has been criticized for inappropriately comparing livestock GHG emissions with transportation, a point one of the paper's authors, Dr. Pierre Gerber, conceded (Armstrong, 2010; Black, 2010).

Efficiency of grain feeding—Most feed grains are highly nutritious grasses and readily amenable to ruminant diets. As a consequence, feeding grain to cattle after they have had sufficient opportunities to grow on forage-based diets often shortens the period from birth to slaughter, while yielding the largest, highest-grading carcasses (see table 1). Shortening the production period reduces ownership costs (e.g., land use, interest expenses, etc.) and allows for more intensive use of land resources. Although the long-yearling, grain-fed system and grass-finished systems can incur the highest ownership costs because they require the most time between birth and slaughter, long-yearling feeding programs often produce larger carcasses, giving them a cost-per-unit advantage over the generally smaller carcasses from grass/forage-fed beef (see table 1). Excluding veal production, calf-fed systems offer the shortest birth-to-slaughter period and, at times—especially when grain prices are relatively low—can incur the lowest costs per unit (see break even “prices” in table 1). Based on these factors, more land will be required to produce a given quantity of grass-fed beef (or less beef production will occur per unit of land) than conventional beef because of the extended periods on pasture, potentially encouraging the use of marginal land more prone to erosion and other adverse effects and increasing ownership costs per unit of beef produced (e.g., Acevedo et al., 2006).

Without current formal analyses, actual conversion rates for grain per unit of beef produced are not available, and informal estimates range widely. As stated previously, feedlot conversion (for the 400-500 pounds gained in the feedlot) is about 5-7 pounds of feed (dry-matter basis) per pound of gain, which is not all beef. At this point, formal analyses have not been done because of the challenge created when allocating fed grain to the myriad products from cattle (or other livestock). In addition to beef, cattle provide dairy products, offal, hides, blood, and the raw materials for other useful pharmaceutical, cosmetic, and industrial products. Inedible and edible animal byproducts, including hides and variety meats, account for 10 percent or more of the value of a live animal and, in addition to their domestic value, contribute as much as a fourth of the value of beef and beef product exports (Marti et al., 2011; Marti and Johnson, 2010). After accounting for the production of products and byproducts from U.S. cattle and accounting for forage-based gains, the average quantity of grains fed to produce a pound of beef (net of associated byproducts) falls below the feedlot conversion of 5-7 pounds of total feed.

Taste and appearance—Well marbled beef is a direct result of cattle being fed grain, and it is one of the most easily distinguished attributes preferred by consumers because of the tenderness and flavor it lends to meat. Meat from cattle finished on grain-based diets will have whiter fat, both outside (e.g., backfat, seam fat) and inside (marbling) muscles, as opposed to the yellow fat of forage-finished beef. Grain-fed beef generally will have a milder flavor and brighter color than forage-finished beef. Grass-fed animals generally have less total fat per animal than grain-fed animals. Beef produced from grass-finished animals is inherently leaner, but, as a reviewer pointed out, there is not much difference in the fat content of trimmed cuts. Grass-finished beef does not exhibit the marbling achieved through conventional grain-fed beef production. Although grass-finished cattle can grade Choice when provided proper forages, grass-finishing yields smaller carcasses with

yellow fat that most often grade Select or lower. Yellow fat develops from higher levels of carotene and gives beef a more robust beef flavor that some consumers prefer. Age of animal at slaughter also can affect tenderness, with younger animals generally being more tender. Umberger et al. (2001) found that 23 percent of U.S. consumers surveyed preferred Argentine grass-fed beef over U.S. grain-fed beef and were willing to pay a premium for it (\$1.36 per pound). Another 15 percent of consumers were indifferent to the two choices. Abidoye et al. (2011) found that consumers were willing to pay a premium of \$3.44 per pound for grass-fed over grain-fed beef.

Most consumer preference studies, however, indicated that those surveyed prefer the taste and tenderness associated with white-fat marbling (e.g., Brewer and Calkins, 2003; Sitz et al., 2005). Consumers discounted grass-fed beef based on flavor and sensory attributes by an average of \$0.36 per pound in one study (Umberger et al., 2009) and \$0.55 to \$0.82 per pound in another study (Umberger et al., 2001). Umberger et al. (2001) found that 62 percent of the U.S. consumers surveyed who preferred U.S. grain-fed beef over Australian grass-fed beef were willing to pay a premium of \$1.61 per pound for domestic beef.

Nutritional profiles—Although some statistically demonstrable differences exist in the research—most notably with saturated fats and omega-3 fatty acids (table 2)—some studies have found that some differences in the nutritional content of products produced in one system are either small in absolute value or not statistically significant compared with those of another (Gilmore et al., 2010; Daley et al., 2010; Smith-Spangler et al., 2010; Auld, 2004; Duckett et al., 2009). For example, Duckett et al. (2009) and Leheska et al. (2008) found no differences in protein or cholesterol in *Longissimus dorsi* muscles of grain-fed and grass-fed cattle.

While both grain-fed and grass-fed beef contain virtually the same fats, fatty acids, and other nutrients, each product offers slightly different fatty acid/nutrient profiles (e.g., Duckett et al., 2009; Faucitano et al., 2008; Leheska et al., 2008) (see table 2), and health-conscious consumers' fat-based preferences can differ from taste and sensory conscious consumers (Umberger et al., 2009; McCluskey et al., 2005). For example, Umberger et al. (2009) found a \$0.67-per-pound grass-fed premium associated with information on fat content and fatty acid profile over grain-fed beef. McCluskey et al. (2005) found a \$5.65-per-pound premium on “low fat and calories” steak over that with “high fat and calories.”

Grass-fed beef offers higher omega-3 fatty acids per unit of total fat and higher ratios of omega-3 to other fatty acids (see table 2). McCluskey et al. (2005) observed that consumers were willing to pay a premium of \$3.42 per pound for a steak with higher levels of omega-3 fatty acids. While there is virtually no difference in cholesterol content per unit of product between grain-fed and grass-fed beef (e.g., Duckett et al., 2009; Leheska et al., 2008; not shown in table 2), some evidence suggests that a premium would exist for meat with lower cholesterol levels (Bellhouse et al., 2010; Adhikari et al., 2006).

Table 2

Summary of studies comparing fatty-acid profiles for beef products from grain-fed beef systems with grass-fed alternative production systems¹

Study/production system (units)	Saturated fatty acid ²	Omega fatty acid ratio (n-6:n-3) ²	Mono-unsaturated fatty acid ³	Poly-unsaturated fatty acid ³	Omega-3 fatty acid (n-3) ³	Trans-fatty acid ²	Conjugated linoleic acid ³
<i>Units vary by study</i>							
Leheska et al. (2008):							
Conventional (g/100 g fat) ⁴	45.1 ^s	13.6 ^s	46.2 ^s	2.77 ⁿ	0.19 ^s	6.04 ⁿ	0.48 ^s
Grass (g/100 g fat) ⁴	48.8 ^s	2.78 ^s	42.5 ^s	3.41 ⁿ	1.07 ^s	5.3 ⁿ	0.65 ^s
Faucitano et al. (2008):							
Grass		1.2 ^{nt}					
Low concentrate (grain content)		1.76 ^{nt}					
High concentrate (grain content)		2.25 ^{nt}					
Razminowicz et al. (2006):							
Pasture-derived steers and heifers (grass/forage fed) (g/100 g beef) ⁵	0.581 ^m	1.7 ^s	0.549 ^m	0.151 ⁿ	0.049 ⁿ		
Conventional and heifers (grain-fed) (g/100 g beef) ⁵	0.621 ^m	3.5 ^s	0.585 ^m	0.149 ⁿ	0.037 ⁿ		
Duckett et al. (2009):							
Finished on concentrate (percent by weight of fat)	41.46 ^s	3.63 ^s	46.08 ^s		0.51 ^s		
Finished on pasture (percent by weight of fat)	46.97 ^s	1.56 ^s	36.52 ^s		0.73 ^s		
Finished on concentrate ⁶ (mg/85.5 g rib-eye steak)			1.760 ^s				0.115 ^s
Finished on pasture ⁶ (mg/85.5 g rib-eye steak)			0.730 ^s				0.054 ^s

g=Grams.

mg=Milligrams.

Statistical indicators: s = statistically significantly different at P<.05; m = statistically significantly different at .05<m<.10; n = not statistically significant difference; nt = not tested.

¹Units across studies are different. As a result, while numbers in columns within each study are directly comparable, they are not directly comparable across studies.²Lower values are better for human health.³Higher values are better for human health.⁴Grams of fatty acid per 100 grams of total fat.⁵Grams of fatty acid per 100 grams of total beef.⁶Grams of fatty acid per fixed quantity of final product.

Less Tangible Attributes

Another group of attributes are either “bundled” with other attributes and difficult to separate or the differences they make in the end product are small or not statistically significant. These attributes include animal welfare issues and some nutritional and healthfulness claims. Van Loo et al. (2012) observed that, while “[c]onsumers often have the perception that organic foods are safer and healthier than conventionally grown foods...most of the research conducted on organic-based foods has concluded that there is no evidence that organic food is safer, healthier, or more nutritious.” “Grass-fed” or “natural” claims embody health, environment, and animal welfare factors for some consumers, but are represented by only one collective premium (Abidoye et al., 2011). “Local” can also embody a number of attributes—healthfulness, quality, food safety, and others—that are difficult to quantify and value separately (Onozaka et al., 2010).

Animal welfare—For optimal animal performance in all livestock production systems, producers have a vested interest in the well-being of the animals in their care. While consumers are generally unfamiliar with livestock behavior, habits, and needs, many are often critical of the care livestock receive. Tonsor and Olynk (2011) found that media coverage of animal welfare had a small but significant negative longrun impact on pork and poultry demand and no direct effect on beef demand. Research is becoming more animal-centric than anthropocentric in its approach to ascertaining *animal* perceptions of animal welfare standards (e.g., Napolitano et al., 2009; Matthews, 2008).

Consumers express concerns with how animal concentration in confinement systems impacts animals’ space to move, exercise, eat, or drink. Grass-finishing systems often emphasize that lack of confinement enhances the well-being of cattle and the value of their products. Generally, mud, dust, crowding, and exposure to disease agents associated with livestock production are minimal for animals on pastures as a result of their relative isolation, although they still suffer injuries and infestations of flies and other pests and health issues in a management system where oversight often is more sporadic and difficult and where treatment often is more stressful and difficult to administer.

Ruminants and other large animals dependent on vegetation for sustenance, however, are typically herd animals, where the herding behavior (natural crowding) evolved for protection from predators and other dangers. In most commercial feedlots, cattle are afforded 150-300 square feet per head, which is sufficient under ideal conditions (Harner and Murphy, 1998). As feedlot conditions deteriorate due to an influx of mud, manure, and other environmental factors, producers can spread cattle into additional pens, allowing pens to dry and reducing moisture-related issues. Depending on current lot conditions, space allocations per head can be as much as 400 square feet per head or more.

Manure accumulation in feedlots becomes a problem when environmental moisture increases and manure management strategies are compromised. While mud and manure on cattle occurs, especially during rainy periods, price discounts for muddy cattle marketed from feedlots and increased costs of gain provide additional economic incentives for producers to minimize mud/manure issues.

Food safety—The safety and security (i.e., maintaining a continuous flow of safe, wholesome product to consumers) of beef and other meat products depends on economically successful animal husbandry in all production systems, where adulterants, diseases, bacteria, and environmental impacts are minimized. In a study of 14 of the most costly U.S. foodborne pathogens, *Escherichia coli* (both O157:H7 and shiga-toxin-producing *E. coli* (STEC) non-O157) accounted for an estimated \$279 million of the \$14 billion in total annual costs, and *Salmonella enterica* accounted for \$3.309 billion of the total (Batz et al., 2012). Of the 14 pathogens studied, those found in beef accounted for \$1.356 billion of the total annual costs attributed to foodborne pathogens. *E. coli* (particularly O157:H7) and *Salmonella* spp are two of the most significant pathogens found in beef. Food safety is a function of both pathogen prevalence and resistance to antimicrobial drugs (AMDs) across all production systems—organic, natural, and conventional—at both cattle and beef production levels.

Prevalence: Cattle are considered major reservoirs of *E. coli* O157:H7, and manure is a source of contamination for food and water (Reinstein et al., 2009). Often the path to beef contamination by foodborne pathogens occurs through the potential for cross contamination from either contaminated cattle or contaminated beef—often beef trim, a component of ground beef. For example, Zhang et al. (2010) attributed to trim the higher prevalence rates found in ground beef versus beef cuts (e.g., steaks). Beef often becomes contaminated through exposure to hides, digestive system contents, or manure during processing. Prevalence is generally not statistically different between cattle production systems (Morley et al., 2011; Reinstein et al., 2009) or products from those systems (Smith-Spangler et al., 2010; Zhang et al., 2010; Miranda et al., 2009; LeJeune and Christie, 2004). Zhang et al. (2010) alluded to the potential for cross-contamination of naturally and conventionally produced beef because grass-fed beef may more often be processed in smaller plants where contamination types and rates are consistently different from that of large facilities where most conventional beef is processed.¹⁵

Resistance: As foodborne pathogens infect humans, causing foodborne illness, resistance of pathogens to various antibiotics used to treat the illness becomes a relevant food-safety issue. While research has demonstrated that differences in microbial contamination between cattle or beef from each production system are not often statistically significant, evidence for resistance has been mixed and results can vary by pathogen. While resistance is generally greater in systems using AMDs in cattle production (conventional) compared with non-AMD (natural or organic) systems, the differences are not always large or statistically significant and results vary by drug (Morley et al., 2011; Rao et al., 2010; Reinstein et al., 2009).

Counter to the general rule, Reinstein et al. (2009) reported higher resistance of *E. coli* O157:H7 to some drugs in natural and organic production systems compared with conventional production, however, both statistically significant and nonsignificant differences were generally small. Miranda et al. (2009) and Smith-Spangler et al. (2010) found greater resistance to AMDs in conventional production compared with organic beef products, with some small statistically significant differences for some AMDs. Differences may

¹⁵Note that organic beef cannot be processed simultaneously with either natural or conventional beef—organic processors must be certified and lines must be cleaned between processing nonorganic and organic beef.

become most relevant when bacterial counts are sufficiently high as to cause illness in humans.

In studies finding small differences, the differences are often characterized by authors as being of “questionable practical relevance” (Smith-Spangler et al., 2010) or of low prevalence with clustering of positive samples (Morley et al., 2011). In addition, several authors pointed out that potential sources of resistance could be common across beef production systems. For example, heavy metals (e.g., copper and zinc) often are included in feed rations to meet nutrient requirements. Reinstein et al. (2009) reported on the potential for resistance to occur with both natural and organic systems from feeding heavy metals due to their antimicrobial properties. LeJeune and Christie (2004) also mentioned factors other than exposure to preharvest subtherapeutic uses of AMDs as sources for resistance.

Pre-harvest interventions: While food safety is largely an issue after cattle leave the farm or feedlot, a number of preharvest interventions have the potential to advance the safety of final products. For example, recent developments in vaccines for *E. coli* and *Salmonella* spp. and feeding regimes may minimize pathogen levels in live animals (Jeong et al., 2011; Oliver et al., 2009; Dodd, 2010). For some vaccine interventions, reduced shedding of pathogens is short-lived, and longer-term immunization is questionable (Khare et al., 2010; Oliver et al., 2009). Further, it was not until the introduction of “edible vaccines” that some of these preharvest interventions became economically feasible (Oliver et al., 2009).

Willingness to pay: While few studies of willingness to pay focus on specific beef pathogens, consumers are willing to pay premiums for beef products they perceive as healthier, and evidence also indicates premiums for foods when accompanied with credible health information (McClusky et al., 2005; Umberger et al., 2009). Although not specific to beef, some research indicates that willingness to pay declines with increasing consumer tolerance of risk of food-borne pathogens and illnesses (Hammitt and Haninger, 2007; Brown et al., 2005). Hammitt and Haninger (2007) found that the estimated willingness to pay was higher for risks transmitted on chicken than on ground beef or packaged deli meat, but they did not report separate values attributable to ground beef only. Fingerhut et al. (2001) compared willingness to pay for beef treated by irradiation, steam pasteurization, hot water pasteurization, and no treatment (in order of declining antimicrobial efficacy). Fingerhut et al. (2001) also found that 60 percent of consumers preferred irradiated beef, that all treatments were preferred to no treatment, and that consumers were willing to pay an average premium of \$0.36 per pound of treated beef. Fingerhut et al. (2001) felt that premiums could cover costs of the three technologies. Nayaga et al. (2006) found that consumers in select U.S. markets were willing to pay a premium of \$0.77 per pound for irradiated ground beef and estimated that this premium would exceed the cost of irradiation.

Outlook for Beef Production and Consumption

Natural, organic, and grass-fed beef production offer consumers and producers commercially viable alternatives to conventional beef production. Beef produced from each of these systems has different attributes that may appeal to various consumers. At present, beef products from alternative production systems likely account for more than 3 percent of the market, with estimated annual growth rates at 20 percent. Continued growth at current rates could double market shares for these products every 5 years, although it is unlikely that such growth will continue beyond a certain threshold. As this threshold is met, market shares for alternatively produced beef products will increase while the market share for conventional grain-fed beef decreases.

Numerous studies have documented the extent to which consumers are willing to pay premiums over prices for conventional grain-fed beef for certain characteristics found in grass-finished, natural, or organic beef. At present, producing alternative beef products generally costs more than producing conventional grain-fed beef products (see table 1). As supplies of beef from alternative production systems increase to meet and exceed demand, premiums will likely decline. As a result of declining relative prices and unless costs decline as well, profit margins for alternative beef products will likely narrow.

Producers and consumers are increasingly better informed about the relative attributes of products from each system. If this information alters consumer views of the tradeoffs associated with each production system, consumers' willingness to pay premiums for alternative beef products may change. The sustainability of each of these beef production systems, including economic sustainability, will be determined as consumers assess and establish the value of various product attributes.

Beef production systems offer a variety of tradeoffs, including land reallocated to pasture for forage-based systems versus cropland for food and livestock feed, selection programs that tailor cattle genetics to alternative beef production technologies, nutrition, and carcass characteristics. For example, as pasture- and forage-intensive programs become more widespread, cropland may have to be reallocated to pastureland or forage production to provide the high-quality forages necessary to achieve adequate levels of finish. Some studies suggest that shifts in land-use allocations may increase both GHG emissions by range livestock and incentives to bring sensitive marginal land into production. At the same time, the production and marketing of beef through local production systems may compromise production/processing efficiencies through use of facilities with smaller slaughter capacities, lost byproduct values, and generally higher costs of production (Johnson et al., 2012). With continued growth, the adoption of alternative production systems will continue to emphasize animal welfare, environmental concerns, and food safety and nutrition issues, as well as tradeoffs in resource use. Additional research may demonstrate advantages for a particular beef production system over another system.

Comparative advantages will shift cattle production to those areas with the resources that support each production technology. For example, areas with the quality forages necessary to finish cattle to acceptable grades or corn-producing areas with a comparative advantage in their ability to feed coproducts from ethanol production. The same kinds of shifts will likely occur as areas with comparative advantages for organic production become better defined. Alternatively, cattle may be moved from one area of the country to another to meet forage needs and demands for specific attributes, perhaps altering the concept of locally sourced beef. To the extent that forage-based technologies replace grain feeding, the demand for corn for livestock feed will also decline, freeing land that could be diverted to pasture or other crops. However, cropland reallocation could be complicated by competing uses, such as growing cellulosic material to produce ethanol, which could affect the amount of land available to produce alternative beef products.

It may also be necessary to vary selection programs to tailor cattle genetics amenable to alternative beef production technologies. Just as with conventional grain feeding, alternative beef production systems will take advantage of genetic cattle strains that perform better under each production technology.

The current transportation and marketing infrastructures were developed in response to the demand for less expensive food and modes of moving food from production areas to consumption areas. Improvising efficient infrastructures for the distribution of products from alternative beef production systems and from local producers has already led to refined definitions for some concepts at wholesale and retail levels like “local.” For example, slaughter and processing facilities would need to be developed (or in some areas, growth in consistent slaughter supply from niche market producers) to optimally provide beef products from each system. Infrastructures must be developed and implemented to ensure process verification, moving information about an animal from farm to market, and other issues.

Local processors are seldom equipped to capture efficiently all the byproducts available from processing cattle, which affects per-unit costs and returns. At least partially due to high implementation costs (Antle, 2000), smaller entities are sometimes allowed flexibility in complying with regulatory protocols aimed at pathogen reduction, environmental preservation, record keeping, employee well-being, or other objectives (e.g., *the Federal Register*, 2012; Crutchfield et al., 1997; *the Federal Register*, 1993). Providing locally sourced beef strains small-scale slaughter capacity in some areas. On the other hand, alternative small-scale slaughter and processing facilities are not economically feasible in all areas due to a lack of consistent supplies of market-ready livestock (Miltner, 2010; Zezima, 2010; Johnson et al., 2012). As demand increases for products from alternative beef production systems, the market forces that bring production and consumption of these alternative beef products into equilibrium may be a catalyst for change in the U.S. beef industry.

Recent and growing interest in locally sourced foods may create a closer relationship between alternative agricultural production systems and consumers, providing opportunities for information exchange and educating consumers about food production. Farmers’ markets and other local venues are popular ways in which natural and organic products, including beef, pork, and poultry, are marketed and will likely continue to grow in the foreseeable future.

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