Factors Affecting the Palatability of Lamb Meat

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Introduction

In the last 43 years, per capita consumption of lamb in the United States has declined to a level of 0.81 lb per person annually on a boneless, retail weight basis (CattleFax, 2003; Figure 1). In contrast, per capita consumption of total meat products has increased 28% to about 194 lb per person annually in this same time period (Figure 2). In 2003, per capita consumption of beef, pork, poultry and fish products was estimated at 62, 48, 68,and 15 lb (boneless, retail weight basis), respectively. These consumption patterns indicate that Americans continue to consume greater amounts of meat in their diet; however, lamb consumption continues to decline.

In a survey conducted of 600 households (Ward et al., 1995; Tulsa, OK), consumers were asked to rank seven meats including beef, chicken, fish, lamb, pork, turkey, and veal on taste, cholesterol content, nutritional content, economic value, fat, convenience, and overall preference (scale: 1st would be most desirable and 7th would be least desirable for these traits). Consumers identified taste as one of the most important factors when purchasing meat and ranked lamb last (lowest preference) among the seven meats for taste and overall preference (Table 1). Consumers ranked lamb 5th for cholesterol level, 6th for nutritional content, and 5th for fat level. Lamb is higher in polyunsaturated fatty acids and conjugated linoleic acid (anticarcinogen), and lower in total fat content than grain-fed beef (Figure 3); however, most consumers appear unaware of potential nutritional benefits from including lamb in the diet. We all must do more to inform consumers about the quality, tenderness, and potential health benefits from including lamb in the diet.

Shelf-Life

Consumers rely on the visual appearance of meat products to indicate its freshness. In red meats, myoglobin is the principle component responsible for meat color. Oxidation of myoglobin during refrigerated storage results in the brown discoloration forming on the surface of exposed meat cuts. Research has shown that consumers will not purchase cuts once the brown discoloration reaches 30 to 40% of total surface color. Wulf et al. (1995) has shown that supplementation of vitamin-E to finishing lambs can increase muscle α-tocopherol levels and delay oxidation of myoglobin to extend the shelf-life of fresh lamb products (Figure 4; black bars). These researchers found that supplementation of 500 IU Vitamin E per lamb per day for a 56-d feeding period would extend shelf-life of lamb by approximately 4-d. Turner et al. (2002) compared pasture-finished to drylot-finished with 15, 150 or 300 IU vitamin E supplemented per lamb per d for 71 d (Figure 4; gray bars). Muscle α-tocopherol levels for pasture (alfalfa or ryegrass pastures) finished lambs were greater than drylot-finished receiving 15 IU vitamin $E \cdot lamb^{-1} \cdot day^{-1}$ (NRC recommended level) and similar to those supplemented with 150 IU vitamin $E \cdot lamb^{-1} \cdot day^{-1}$. Supplementing finishing diets in drylot with 300 IU vitamin $E \cdot lamb^{-1} \cdot day^{-1}$ increased α-tocopherol levels to the greatest extent with levels at 4.2 μg/g of fresh tissue. Research in beef cattle has shown that the target level for α-tocopherol concentration in muscle tissue is 3.5 μg/g in order to have a significant impact on reducing myoglobin oxidation and extending shelf-life (Arnold et al., 1993). Based on this target level and available data from lamb studies, the apparent feeding level for vitamin E would be 300 to 500 IU vitamin $E \cdot lamb^{-1} \cdot day^{-1}$ for a minimum of 55 d prior to harvest to increase muscle α-tocopherol concentrations and extend shelf-life.

Tenderness

Warner-Bratzler shear force is an objective measure of tenderness used in the research laboratory to evaluate relative differences in tenderness or toughness of meat products. The measurement process involves broiling chops (1" thick) on electric broilers to a medium degree of doneness using an internal thermocouple inserted in the geometric center of every chop. After broiling, chops are cooled, four half-inch cores removed, and cores are sheared using a Warner-Bratzler shear force apparatus to determine the force (kg) required to shear each core in half. Research has shown that the greatest improvements in tenderness of meat products occurs during the postmortem aging process, where meat is held at refrigerated temperatures for extended periods of time. Figure 2 shows that typical postmortem aging curve for lamb loin chops at 1, 3, 6, 12, and 24 d postmortem (Duckett et al., 1998). Shear force values decreased with postmortem aging time resulting in a 46% reduction in shear force from d-1 to d-12 (4.82 kg at d 1 vs. 2.58 kg at d 12).

Breed comparisons for Warner-Bratzler shear force from recent research trials are summarized in Table 3. Burke et al. (2003) evaluated Dorper or St. Croix sires on St. Croix or Romanov x St. Croix ewes. These researchers also compared these crosses to Katahdin lambs that were purchased from a single producer. Shear force measurements were similar between Dorper and St. Croix sires, regardless of ewe breed. However, shear force values for Katahdin lambs were higher, tougher, than the Dorper or St. Croix sired. Shackelford et al. (2003) in a preliminary report of a breeding project underway at Meat Animal Research Center in Clay Center, NE evaluated Finnsheep, Romanov, Dorper, Katahdin, Rambouillet, Suffolk, Texel, Dorset or composite sires on composite (½ Columbia, ¼ Hampshire x ¼ Suffolk) ewes. The shear force measurements reported by these researchers is for a slice shear force instead of the traditional half-inch core that is used in most experimental trials. Shear force values were higher, tougher, for Dorset- and composite-sired lamb than Finnsheep-sired lamb. All other sire breeds (Romanov, Dorper, Katahdin, Rambouillet, and Suffolk) produced lamb with shear force values that were similar to Finnsheep-sired or Dorset and composite-sired lamb. In research conducted at the U.S. Sheep Experiment Station in Dubois, ID, Snowder and Duckett (2003) compared Dorper or Suffolk sired lambs for palatability traits. Dorper-sired lambs produced lamb chops with a lower, more tender, shear force value than those sired by Suffolk. Greiner et al. (2003) evaluated Dorper or non-Dorper (Suffolk at UGA or Dorset at VTU) sires on non-Dorper ewes. Shear force values were lower, more tender, for lamb chops from Dorper-sired lambs than non-Dorper-sired. In a second study, Dorper or Dorset sired lambs were compared to Barbados Blackbelly x St. Croix or Katahdin lambs. Shear force values were greatest, tougher, for Dorset-sired than Dorper-sired or Katahdin lambs. Lamb chops from Barbados Blackbelly x St. Croix lambs were similar to those from Dorset-sired, Dorper-sired, or Katahdin. Research has also shown that lamb chops from animals expressing the callipyge phenotype (specific muscle hypertrophy) is much tougher than normal lamb due to the reduced rate and extent of postmortem aging (Duckett et al., 1998).

Overall, the shear force values reported in the literature for lamb are lower than most beef values. In beef, the threshold value for shear force is considered to be about 4.5 kg. A value below this threshold would indicate that consumers would rate it slightly tender or better for overall tenderness ratings. Threshold values are not available for lamb, but based on shear force values reported for lamb and levels acceptable for beef, it appears that consumers would consider these lamb shear force values highly acceptable for palatability.

Flavor

The basic meaty flavor of meat products resides in the water-soluble fraction; whereas, species-specific flavors are located in the lipid-soluble (fat) fraction (Horstein and Crowe, 1963). Lamb fat has a very unique aroma and flavor, which is the subject of numerous reviews on the subject (Jacobson and Koehler, 1963; Field et al., 1983; Jamora and Rhee, 1998; Duckett and Kuber, 2001). Several compounds (branched chain fatty acids, carbonyl compounds, sulfur-containing compounds, lipid oxidation products, phenols, and basic compounds) are believed to impact lamb flavor; however, the specific compound(s) responsible for the characteristic lamb flavor and odor have not been identified. One problem with flavor analyses is the reliance on human evaluation in trained sensory panels or trained flavor description panels to detect differences in flavor intensity or characteristics. Research shows that flavor ratings appear to be largely related to the panelist's preference and previous exposure to lamb (Sanudo et al., 1998; 2000). Volatile flavor analyses can be utilized to assess differences in volatile compounds that relate to flavor; however, this process usually produces over 200 different volatiles compounds from lamb that have to be related to the changes in intensity of lamb flavor as evaluated by sensory panelists (Young et al., 1997). In other words, evaluations of flavor are some of the most difficult and complex analyses conducted in the meat quality research laboratory. Additional research is greatly needed in this area to help ascertain ways to minimize the intensity of lamb flavor for increased acceptability by consumers.

Breed. Cramer et al. (1970a) compared three breeds (Rambouillet, Targhee, and Columbia) on mutton flavor intensity. Mutton flavor intensified as the fineness of the wool increased with breeds. In a second study (Cramer et al., 1970b), five breeds (Romney, Hampshire, Columbia, Rambouillet, and Merino) were compared for intensity of mutton flavor.

Mutton flavor intensity was similar between the breeds but unsaturated fatty acid content was higher in the finer-wool breeds. Several other studies comparing breeds or sires (Fox et al. 1962, 1964; Crouse et al., 1981; Dransfield et al., 1979; Mendenhall and Ercanbrack, 1979) have been conducted but differences in lamb flavor due to breed or sire were not observed. In a comparison of sire breeds (Dorper vs. Suffolk), Snowder and Duckett (2003) reported a greater flavor preference for Dorper-sired lamb by sensory panelists.

Pasture type. Comparisons between pasture type and lamb flavor intensity show that the type of pasture consumed prior to harvest can alter lamb flavor. In evaluations of finishing lambs on perennial ryegrass or white clover, Cramer et al. (1967) reported higher, more intense lamb flavor intensity for lamb from animals grazing white clover pastures compared to perennial ryegrass prior to harvest. In a follow-up study (Shortland et al., 1970), they concluded that flavor intensity ratings were higher, more intense, after only three weeks of grazing the white clover pastures. In comparisons of grazing ryegrass or alfalfa pastures before harvest (Nicol and Jagusch, 1971; Park et al., 1972a), lamb flavor was rated more intense in lambs that grazed alfalfa prior to harvest. Panelists described the lamb from animals grazing alfalfa as having greater foreign flavors and aromas, which reduced overall acceptability of this lamb product. Park et al. (1972a) also examined changing pasture type (alfalfa to grass for 0, 1, or 2 wk) prior to harvest and found that foreign flavors and odors were reduced with increased time on grass pastures before harvest. Overall acceptability ratings for the lamb from grass pasture 2 wk before harvest were similar to that from animals which grazed grass pastures for the duration of the entire study (13 wk).

Grain Feeding. Finishing lambs on grain alters fat composition and reduces lamb flavor intensity similar to differences observed between grain-fed and grass-fed beef products. Rousset-

Akrin et al. (1997) reported higher, more intense sheepmeat flavors for ram lambs finished on pasture with a slow rate of growth compared to those finished on concentrates (42% corn and wheat diet) or on pasture with a high rate of growth. Borton et al. (1999) reported more off-odors and off-flavors in loin chops from lambs finished on ryegrass compared to concentrates. Kemp et al. (1981) compared pasture only, pasture plus creep (13% crude protein), or drylot plus creep at two protein levels (13% or 16% crude protein) for effects on lamb flavor intensity. Lamb from animals which solely grazed pasture was rated the most highest, most intense for flavor; whereas, lamb from animals grazing pasture plus creep had the lowest, most desirable flavor ratings. Both Fisher et al. (2000) and Sanudo et al. (2000) compared lambs of different breeds finished under various production systems for flavor intensity as measured by sensory panelists in three countries. Forage-fed lambs had higher levels of omega-3 fatty acids and concentrate-fed lambs had higher levels of omega-6 fatty acids. Panelists from the United Kingdom and Britain preferred forage-fed lamb; whereas, panelists from Spain preferred concentrate-fed lamb. Priolo et al. (2002) evaluated finishing lambs on grass pastures or concentrates and found that concentrate-fed lambs had lower, less intense, livery off-flavor rating.

In summary, research shows that genetics has a minor influence on lamb flavor; however, interactions between breed and nutritional regimen may occur. Nutritional regimen before harvest has a large impact on fat composition and flavor ratings. Intensity of flavor is increased with grazing of white clover and alfalfa, which can be reduced by switching lambs to grass pastures for a 2-week period just prior to harvest. Finishing on concentrates alters fat composition and reduces lamb flavor intensity. Additional research is needed to develop a greater understanding of factors regulating lamb flavor intensity and factors that may help to minimize intensity for increased consumer acceptance.

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Figure 1. Per capita lamb consumption (boneless, retail weight basis) in the United States from 1960 to 2003 (Cattle-Fax, 2004).

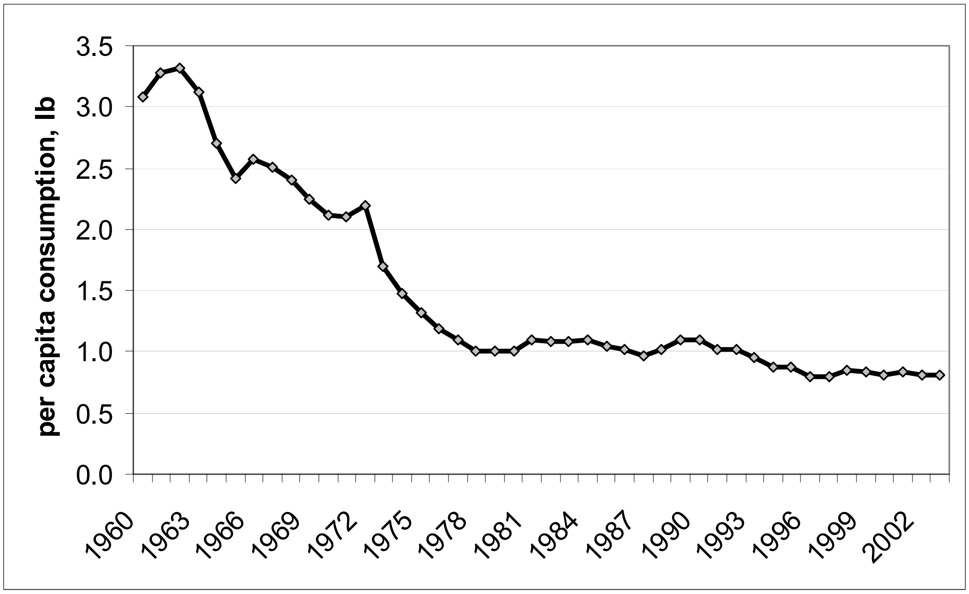

Figure 2. Per capita consumption of total meats (beef, pork, lamb, veal, poultry & fish; boneless weight basis) in the United States from 1960 to 2003 (Cattle-Fax, 2004).

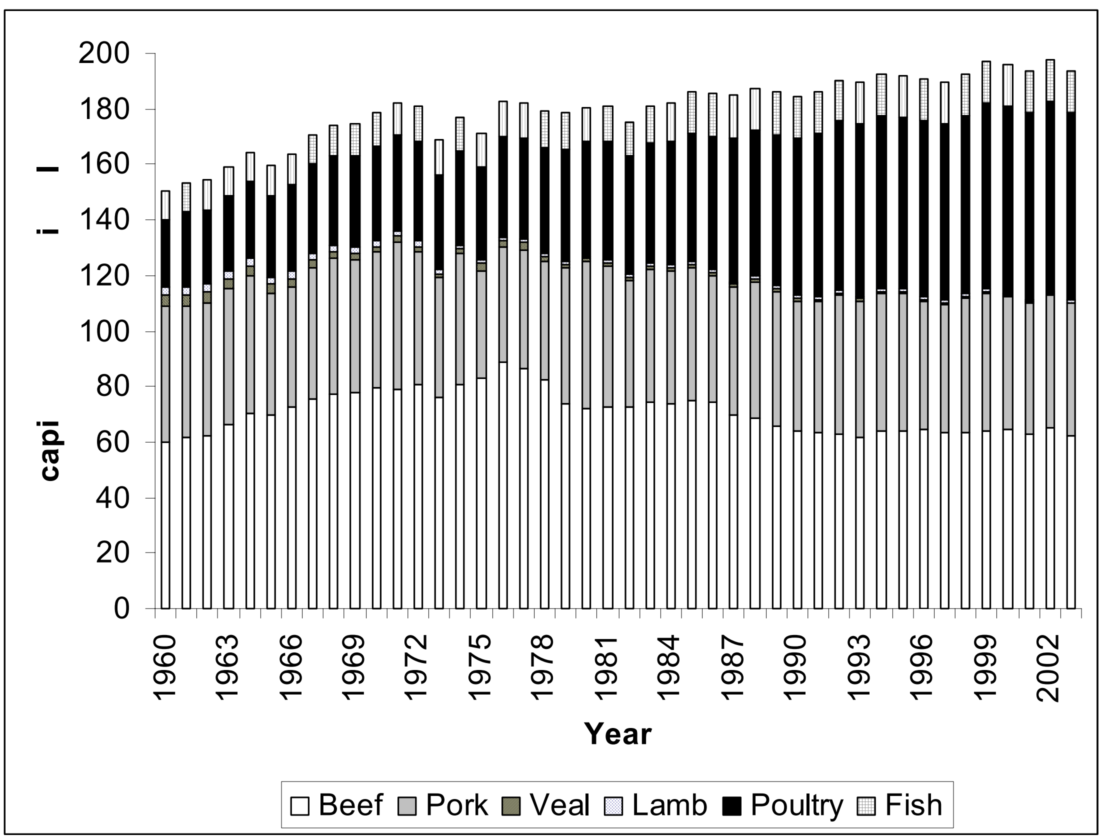

Table 1. Consumer preference of lamb versus other meats (beef, chicken, fish, pork, turkey, and veal) for taste, cholesterol, nutritional content, economic value, fat, convenience, and overall preference (Ward et al., 1995).

Rank	**Taste**	**Cholesterol level**	**Nutritional content**	**Economic value**	**Level of fat**	**Convenience**	**Overall**
1[a]	Beef	Fish	Fish	Chicken	Fish	Beef	Beef
2	Chicken	Turkey	Beef	Turkey	Turkey	Chicken	Chicken
3	Pork	Chicken	Chicken	Beef	Chicken	Pork	Turkey
4	Turkey	Veal	Turkey	Pork	Veal	Turkey	Fish
5	Fish	**Lamb**	Veal	Fish	**Lamb**	Fish	Pork
6	Veal	Pork	**Lamb**	Veal	Beef	Veal	Veal
7[b]	**Lamb**	Beef	Pork	**Lamb**	Pork	**Lamb**	**Lamb**

[ab]Rank: 1 = highest preference of the seven meat products for that trait and 7 = lowest preference of the seven meat products for that trait.

Figure 3. Fat and cholesterol content of lamb, grain-fed beef or grass-fed beef analyzed in research laboratory at UGA.

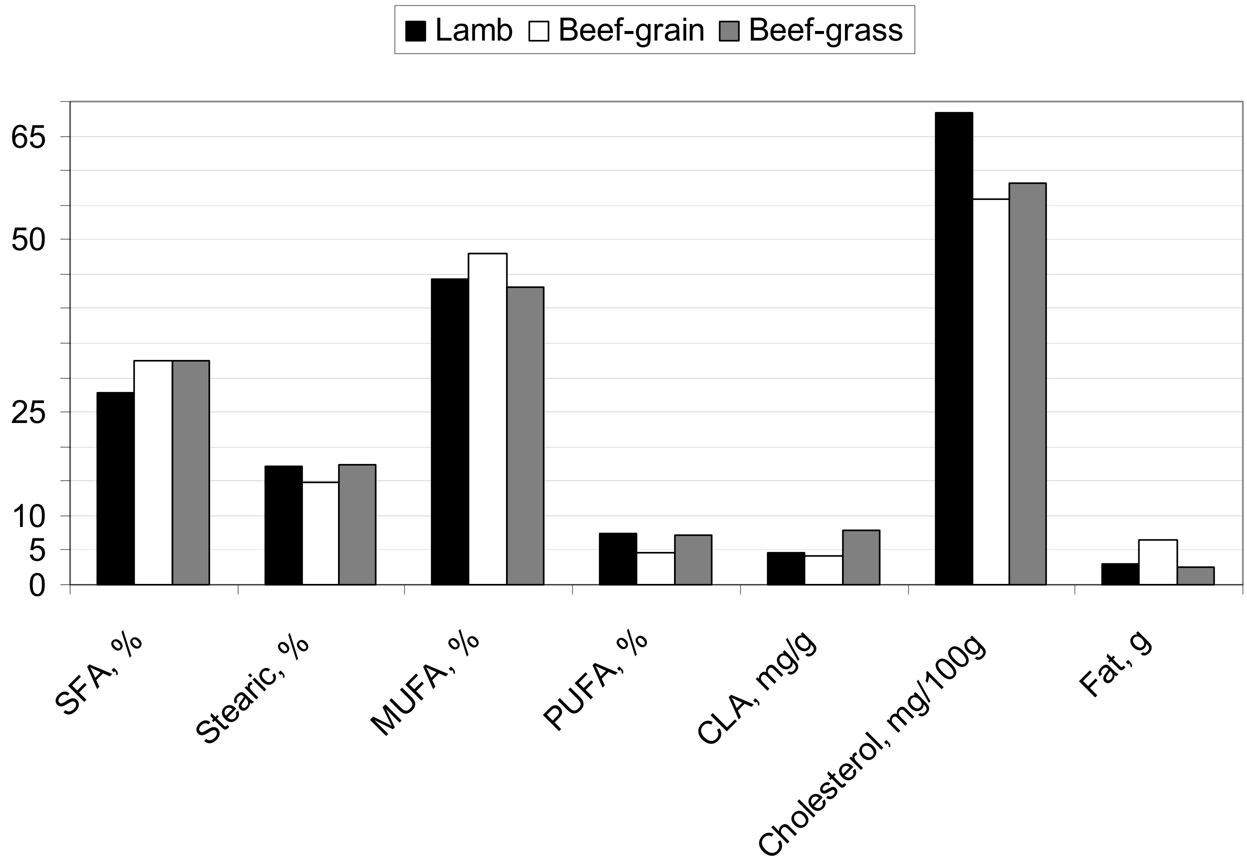

Figure 4. Alpha-tocopherol level (ug/g lean tissue) for lambs finished in drylot and supplemented with vitamin E or finished on pasture (Black bars = Wulf et al., 1995; Gray bars = Turner et al., 2002).

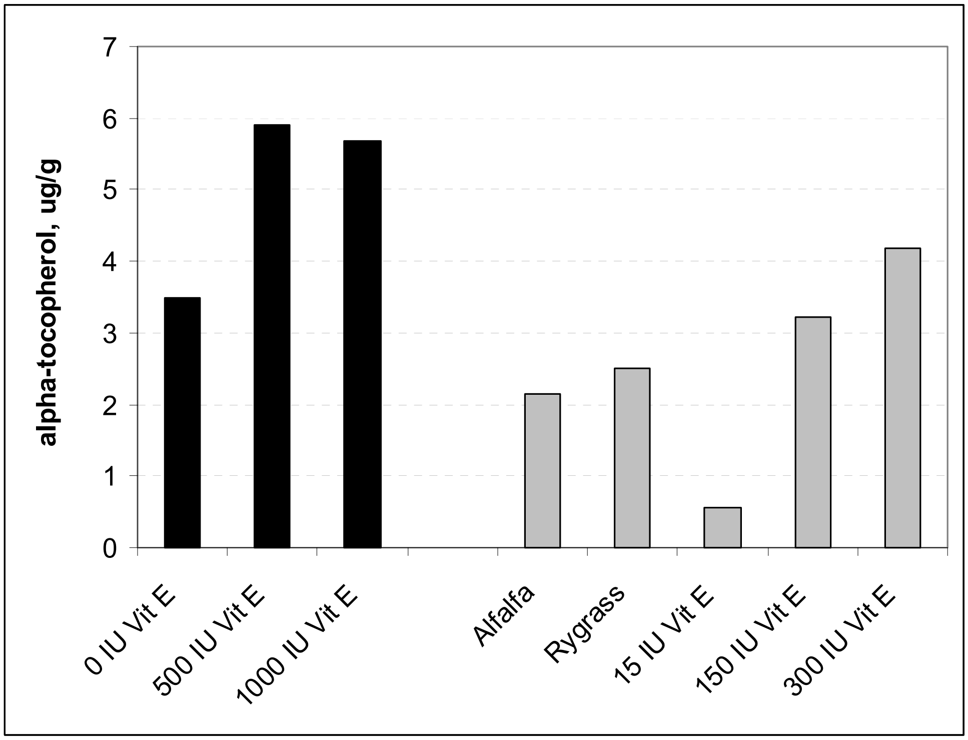

Figure 5. Change in Warner-Brazler Shear force across the postmortem aging curve.

Table 2. Summary of shear force values of lamb loin chops from recent research trials.

Sire Breed	Dam Breed	Sex	WBS,kg	Reference
Dorper	St. Croix	W	2.53[b]	Burke et al. 2003
Dorper	Romanov x St. Croix	W	2.42[b]	Burke et al. 2003
Katahdin	Katahdin	W	3.65[a]	Burke et al. 2003
St. Croix	St. Croix	W	2.23[b]	Burke et al. 2003
St. Croix	Romanov x St. Croix	W	1.86[b]	Burke et al. 2003
Finnsheep	Composite	E/W	17.3[b]	Shackelford et al., 2003
Romanov	Composite	E/W	22.7[ab]	Shackelford et al., 2003
Dorper	Composite	E/W	23.0[ab]	Shackelford et al., 2003
Katahdin	Composite	E/W	21.3[ab]	Shackelford et al., 2003
Rambouillet	Composite	E/W	22.6[ab]	Shackelford et al., 2003
Suffolk	Composite	E/W	22.7[ab]	Shackelford et al., 2003
Texel	Composite	E/W	21.3[ab]	Shackelford et al., 2003
Dorset	Composite	E/W	25.5[a]	Shackelford et al., 2003
Composite	Composite	E/W	27.6[a]	Shackelford et al., 2003
Dorper	Columbia	W	2.80[b]	Snowder and Duckett, 2003
Suffolk	Columbia	W	3.98[a]	Snowder and Duckett, 2003
Dorset or Suffolk	Dorset or Suffolk	E/W	3.03[a]	Greiner et al., 2003
Dorper	Dorset or Suffolk	E/W	2.39[b]	Greiner et al., 2003
Dorper	Dorset	E/W	2.37[b]	Greiner et al., 2003
Dorset	Dorset	E/W	3.17[a]	Greiner et al., 2003
Barbados blackbelly	St. Croix	E/W	2.69[ab]	Greiner et al., 2003
Katahdin	Katahdin	E/W	2.49[b]	Greiner et al., 2003
Callipyge/Dorset	Dorset	W	5.5[a]	Duckett et al., 1998
Dorset	Dorset	W	3.0[b]	Duckett et al., 1998