J. King Saud Univ., Vol. **3**, *Agric. Sci.* (1), pp. 17-27 (1411/1991)

Physical Separation and Prediction Equations to Assess the Effect of Slaughter Weight on the Distribution of Lean, Fat and Bone in Merino Wether Carcasses

M.A. Abouheif, Y. Al-Haowas and **M.N. Bakkar**
College of Agriculture, King Saud University, Riyadh, Saudi Arabia

Abstract. Forty five imported Australian Merino wethers were equally allotted to three prescribed weight groups of 52, 58 and 65 kg, and slaughtered to compare the effect of slaughter weight on the distribution of lean, fat and bone weight among the wholesale cuts. The results indicated that, the lean weight in leg, shoulder, loin and breast and shank cuts increased nonsignificantly as an average slaughter weight increased from 52 to 58 kg and significantly ($p<0.01$) from 58 to 65 kg. The dissected fat weight in the wholesale cuts increased significantly ($p<0.01$) with increased slaughter weight.

The results also showed that as slaughter weight increased, bone weight increased in a variable trends reflecting the different rates of development among the studied cuts. The correlation coefficients between lean and bone weight in cold half carcass and the corresponding tissue weights in leg cut, and between fat weight in cold half carcass and the fat weight in loin cut were the highest among the other calculated coefficients.

Introduction

Consumer demands and economics will ultimately determine the type of sheep imported to Saudi Arabia in the future. Since preferences for mutton clearly favor larger cuts with reasonable ratio of lean to fat [1], heavier carcasses would be advantageous to both consumer and processor [2]. Heavier lambs are generally considered to be fatter than lighter lambs [1,3,4]. In addition, numerous studies [4,5] have shown that the weight of lean in lamb carcasses increased significantly as slaughter weight increased. Because Australian Merino wethers have not generally been bred for slaughter, their carcass characteristics, especially at heavy weights, have not been studied extensively. Therefore, this study was undertaken to evaluate the effect of slaughter weight on the distribution of dissected lean, fat and bone weight among the wholesale cuts of imported Australian Merino wethers. Also, from the physical separation and the cut-out data, equations were developed to predict the total dissectable lean, fat and bone weight in cold half carcass.

Materials and Methods

Forty five recently imported Australian Merino wethers of the same flock as indicated from their ear tags were purchased from Saudi Livestock Transport and Trading Co. and trucked to the Animal Production Farm, King Saud University. All wethers were individually identified, weighed and equally allotted to three weight groups of 52±2, 58±2 and 65±2 kg. The corresponding ages as determined according to the stage of permanent incisors eruption were 1.5 to 2 years old. The body weight of each wether was again recorded after an 18-hr period without feed. Immediately after weighing, wethers were slaughtered at a commercial slaughterhouse; thereafter, carcasses were returned to the meat laboratory for processing. Carcasses were allowed to chill for 24 hr at 5°C before cold carcass weights were recorded.

All kidney, pelvic and thoracic fat were removed and weighed. Carcasses were then split down the backbone and the right side of each cold carcass was fabricated according to the American National Livestock and Meat Board Standard into wholesale leg, shoulder, loin, rack, breast and shank and flank cuts by the procedure described by Romans *et al.* [6]. Compelete carcass and cut-out data were previously reported by Abouheif *et al.* [7]. Each wholesale cut was trimmed of all external fat (subcutaneous fat), boned out and intermuscular fat was removed. The total of fat trim and intermuscular fat was removed. Intermuscular fat included all fat lying between muscles and between muscles and bones. The total of fat trim and intermuscular fat in each wholesale cut was used as the estimate of dissectible fat. Lean from each cut was used as the estimate of dissectible lean, and the bone from each cut boned out as the estimate of bone. The three components were weighed separately to determine relative proportions within cuts. Also, percentages of dissected lean, fat and bone in cold half carcass were calculated by dividing the combined weight of any component in the right side of the cold carcass by the combined weight of dissectible lean, fat and bone in the right side of the cold carcass × 100.

It should be mentioned that due to some errors in recording the dissectible components of the neck cut, neck weight was not included as side weight or with dissected tissue components. However, while these estimates of dissectible tissues do not represent the actual carcass composition, they should identify the trend for differences in composition among the different slaughter weight groups.

Means, standard errors and correlations were calculated, and Duncan's multiple range test was used to detect differences among individual means [8]. Also, the pooled wholesale cut weights, cold carcass weight and the dissected lean, fat and bone weight in each wholesale cut of all slaughter groups were used as independent variables (X's) to develop equations valid for predicting the total dissected lean, fat or bone weight in cold half carcasses (Y's) of a wide range of slaughter weights (50 to 67 kg) by the use of stepwise regression technique. The stepwise regression technique included the maximum coefficient of determination (R^2) improvement procedure. The maximum R^2 analyses were restricted in that only variable that had an effect with a probability of less than 0.15 were used in the equations, regardless of R^2 improvement. All statistical computations were accomplished by the use of computer program entitled Statistical Analysis System [9].

Results and Discussion

The means dissectible lean, fat and bone weight and their standard errors among the studied wholesale cuts for the various slaughter weight groups of Merino wethers are shown in Table 1. Wholesale cuts differ in economic value because of differences in the amount of lean in each cut and differences in composition. However, the dissected lean weight in leg, shoulder, loin and breast and shank cuts increased nonsignificantly as an average slaughter weight increased from 52 to 58 kg and significantly ($p<0.01$) from 58 to 65 kg. On the other hand, there were no significant differences in lean weights from rack and flank cuts between the various studied slaughter weight groups. Total increase in kilograms of lean deposited in cold half carcasses between the 58 and 65 kg slaughter weight groups indicated lean deposition had nearly 4.9 as much as the increases in lean tissue weight occurred between 52 and 58 kg. This indicates that Merino wethers used in this study showed a marked acceleration in rate of muscle deposition after they attained 58 kg body weight.

Conversely, several reports [10, 11] have indicated that the rate of muscle accretion becomes slower as the animals approach mature size. Therefore, the observable increase in dissected lean weight from heavier Merino wether carcasses is not readily explainable, other than; (a) the wethers were still undergoing an accelerated growth; (b) the increases in lean weight may be associated with an increasing amounts of intramuscular fat which is part of the dissected lean content (12, 13); and (c) the studied wethers were probably representing different strains of different frame sizes [14].

The dissected fat weights from cold half carcasses and all studied wholesale cuts increased significantly ($p<0.01$) as an average slaughter weight increased from 52 to 58 kg and from 58 to 65 kg (Table 1), confirming the results of Kemp et al. [3], Lambuth *et al.* [15] and Jacobs *et al.* [16]. Beitz [11] also stated that as animals approach mature weight, fat accretion in their bodies will continue. This is likely the reason for the increased dissected fat weight as slaughter weight increased.

Table 1. Means and standard errors (SE) for dissected lean, fat and bone weights in wholesale cuts from different slaughter groups[a] of Merino wethers

	Lean				Fat				Bone			
Wholesale cut	52 kg	58 kg	65 kg	±SE	52 kg	58 kg	65 kg	±SE	52 kg	58 kg	65 kg	±SE
Leg, kg	2.81^c	2.95^c	3.23^b	.10	$.36^d$	$.50^c$	$.58^b$	.03	$.78^d$	$.90^c$	$.96^b$	.03
Shoulder, kg	1.92^c	1.94^c	2.29^b	.09	$.33^d$	$.60^c$	$.67^b$	.02	$.59^d$	$.70^c$	$.80^b$	.02
Loin, kg	$.56^c$	$.58^c$	$.84^b$	.06	$.25^d$	$.38^c$	$.51^b$	.01	$.28^c$	$.27^c$	$.35^b$	.02
Rack, kg	.49	.53	.55	.02	$.19^d$	$.41^c$	$.49^b$	.02	.27	.26	.24	.02
Breast and shank, kg	1.14^c	1.15^c	1.36^b	.07	$.48^d$	$.80^c$	$.90^b$	.04	$.55^c$	$.53^c$	$.62^b$	.02
Flank, kg	.32	.33	.38	.04	$.20^d$	$.38^c$	$.48^b$	.03	.01	.01	.01	.01
Cold half carcass, kg[e]	7.24^c	7.48^c	8.65^b	.14	1.81^d	3.07^c	3.63^b	.07	2.48^d	2.67^c	2.98^b	.06

[a] 15 animals/ slaughter group.
[b,c,d] Means bearing different superscripts within each tissue among slaughter groups differ ($p<0.01$).
[e] Neck cut is not included.

Results in Table 1, indicated that bone weight in leg cut, shoulder cut and cold half carcass increased significantly ($p<0.01$) as slaughter weight increased. Bone weight from loin and breast and shank cuts increased nonsignificantly as an average slaughter weight increased from 52 to 58 kg and significantly ($p<0.01$) from 58 to 65 kg. On the other hand, bone weight in rack and flank cuts did not change significantly with increased slaughter weight. Generally, the inconstant changes in bone weight with increased slaughter weight probably reflect the different rates of development among the wholesale cuts as were previously reported [10]. Bone and lean tissues in rack cut seem, however, earlier-maturing tissues than those from other studied cuts. These findings agreed with the results obtained by Lambuth *et al.* [15] who showed that retail rack cut made no significant increase with increased lamb weight. The absolute rises in bone weight in cold half carcass increased with increasing slaughter weights. This result appears to be contradicted with the general concept that bone is an early maturing tissue. However, the possible explanations are: (a) the accelerated increase in lean weight stimulate the bone growth [11]; (b) the continuous grazing of the Merino in their natural habitate probably stimulate the growth of their bones. Van Sickle [17] indicated that moderately exercise had very positive effects on the skeletal muscles, articular cartilage health and trabecular bone size.

Relative tissue deposition may be expressed by relating total kilograms of tissue in the 52 kg slaughter weight group as a percent of the total kilograms deposited at the 65 kg group. These relationships showed that the 52 kg slaughter group included 83.7, 83.2 and 49.9 % of the total carcass lean, bone and fat deposition, respectively. These values coincide partly with the results of Palsson and Verges [10] who reported that relative order of tissue maturation as bone, muscle and fat, respectively. Moreover, the results indicated a carcass lean to bone ratio of 2.92 in the 52 kg slaughter group. This ratio decreased slightly to 2.80 at the 58 kg weight group and then increased to 2.90 in the heaviest weight group (65 kg). However, the increased lean to bone ratio in the 65 kg weight group would be explained by the marked acceleration in the rate of lean deposition that occurred in Merino wethers after they attained 58 kg body weight. Generally, these ratios tended to have a lower values compared with those reported by Rouse *et al.* [12] and Makarechian *et al.* [18].

Carcass composition may be also evaluated by considering the percentages of lean, fat and bone in each wholesale cut. If carcass weight or wholesale cut weight is constant, the measures obtained by the percentages or by weight systems are directly proportional. When carcass weights are variable, as in these data, different conclusions are likely expected. The effect of slaughter weight on the percent dissected lean, fat and bone as a percent of each wholesale cut weight are seen in Table 2. Generally, a significant increase ($p<0.01$) in percent dissected fat in each cut was accompanied by a decrease ($p<0.01$) in percent dissected lean and bone, particularly when slaughter weight increased from 52 to 58 kg. These results revealed much the same trend as those outlined by Kemp *et al.* [3] and Lambuth *et al.* [15] for lambs varying

Table 2. **Percentage means for dissected lean, fat and bone weight as percent of wholesale cut weight**

Wholesale cut[a]	Lean			Fat			Bone		
	52 kg	58 kg	65 kg	52 kg	58 kg	65 kg	52 kg	58 kg	65 kg
	%								
Leg	71.1^{b}	67.8^{c}	67.7^{c}	9.1^{d}	11.5^{c}	12.2^{b}	19.8	20.7	20.1
Shoulder	67.6^{b}	59.9^{c}	60.9^{c}	11.6^{c}	18.5^{b}	17.8^{b}	20.8	21.6	21.3
Loin	51.4^{b}	47.2^{c}	49.4^{c}	22.9^{c}	30.9^{b}	30.0^{b}	25.7^{b}	21.9^{c}	20.6^{c}
Rack	51.6^{b}	44.2^{c}	42.9^{c}	20.0^{d}	34.2^{c}	38.3^{b}	28.4^{b}	21.6^{c}	18.8^{d}
Breast and shank	52.5^{b}	46.4^{c}	47.2^{c}	22.1^{c}	32.3^{b}	31.3^{b}	25.4^{b}	21.3^{c}	21.5^{c}
Flank	60.4^{b}	45.8^{c}	43.7^{d}	37.7^{d}	52.8^{c}	55.2^{b}	1.9^{b}	1.4^{c}	1.1^{d}
Cold half carcass[e]	62.8^{b}	56.6^{c}	56.6^{c}	15.7^{c}	23.2^{b}	23.9^{b}	21.5^{b}	20.2^{c}	19.5^{c}

[a]15 Merino wethers/ slaughter weight group.
[b,c,d]Means bearing different superscripts within each tissue among slaughter groups differ ($p<0.01$).
[e]Neck cut is not included.

in slaughter weights from 36 to 54 kilograms. Jacobs *et al.* [16] concluded that as lambs approach the top of their growth curve they will fatten at a higher rate. Therefore, increased percent fat woold explain why percent bone and lean decreased as slaughter weight increased. This result also indicates bone development, represented as a percent of the total cold half carcass, occurred at a slower relative rate than other tissues at the 58 kg weight group. However, these results coincide with earlier works by Palsson and Verges [10].

On the other hand, there were no significant differences in percent lean, fat and bone in cold half carcasses between 58 and 65 kg slaughter weight groups. It is assumed that the marked increase in lean weight observed at the 65 kg group (Table 1) probably masked the expected proportional increase in dissected fat at that weight. This finding, also agreed with the results obtained by Sents *et al.* [5] who indicated that each tissue component was changing less on a percentage basis at the heavier weights than at the lighter weights due to the mathematical situation of dividing the same weights of growth by a larger value.

In a conclusion, the carcasses from Merino wethers contained on average 56.6-62.8 % lean, 15.7-23.9 % fat and 19.5-21.5 % bone. This agrees with the values obtained from mutton and local breeds on the variability of the relative composition [5, 13, 19]. The correlation coefficients between lean, fat and bone weight in cold half carcass and the corresponding tissue component weights in each studied wholesale cut are shown in Table 3. With the exception of lean and bone weight of rack and flank cuts, there were significant positive correlations ($p<0.01$) between tissue components of cold half carcass and their corresponding tissue components in each wholesale cut. However, the correlation coefficients between lean and bone weight

Table 3. Correlation coefficients between lean, fat and bone weight in cold half carcass[a] and the corresponding tissue component weights in each wholesale cut .

	Cold half carcass		
Wholesale cut[b]	Lean	Fat	Bone
Leg	.764**	.785**	.848**
Shoulder	.677**	.800**	.557**
Loin	.628**	.825**	.776**
Rack	.104	.672**	.173
Breast and shank	.590**	.652**	.614**
Flank	.013	.719**	.124

[a]Neck cut is not included.

[b]n=42.

** $p<0.01$.

Table 4. **Regression coefficients for predicting dissectibe lean, fat and bone weight in cold half carcass[a] from the corresponding tissue component weights in each cut, wholesale cuts weights and cold carcass weight of Merino wethers.**

Independent variables (X's)	Dependent variables (Y's)								
	Lean[b]			Fat			Bone		
	Eq. 1[c]	Eq. 2	Eq. 3	Eq. 1	Eq. 2	Eq. 3	Eq. 1	Eq. 2	Eq. 3
R^2	.81	.94	.97	.94	.97	.99	.89	.97	.98
Intercept	2.99	.66	.58	.29	.05	.12	1.48	.23	.01
Lean in shoulder, kg	2.38**	1.61**	1.34**						
Lean in leg, kg		1.29**	1.22**						
Rack cut, kg			.74						
Fat in shoulder, kg				4.95**	3.46**	2.60**			
Fat in breast and shank, kg					1.31**	1.10**			
Fat in rack, kg						1.62**			
Bone in shoulder, kg							1.89**	1.19**	1.28**
Cold carcass weight, kg								.06**	.04**
Leg cut, kg									.17**

[a]Neck cut is not included.
[b]Dissectible lean, fat and bone weight in cold half carcass (kg).
[c]Eq. 1,3,3= equation No. 1,2,3; each equation was derived by the use of stepwise regression technique.
** $p<0.01$

in cold half carcass and the corresponding lean and bone weight in leg cut, and between fat weight in cold half carcass and fat weight in loin cut were the highest among the other calculated coefficients. The relationship between lean weight in leg cut and lean weight in cold half carcass, confirmed the results obtained by Rouse *et al.* [12] who indicated that as lamb carcass weight increased, the percent lean in leg cut increased more rapidly than the percent lean in the remainder of the carcass. Further, this pronounced relationship may be also due to the fact that leg cut in lamb carcasses contained more lean and bone weight than the remainder of the cuts [12,19].

Although edible portion has been used in evaluating lamb and beef carcasses, the dissected lean content is of more value than edible portion in evaluating nutritive value. Unless the meat is ground or comminuted, most consumers discard the dissected fat from a cooked meat before eating it. Since total dissection is time consuming and expensive, several workers have used sample cuts for predicting the tissue components of the carcasses [20,21]. The relationships between the various wholesale cut weights, dissected tissue component weights in each cut and the cold carcass weight (X's) and the corresponding tissue component weights in cold half carcass (Y) are expressed for Merino wethers by equations presented in Table 4. For each tissue component, the R^2 was improved by the addition of more independent variables to the model. Generally, the R^2 values for the best equations for prediction of dissectible lean, fat and bone weight in cold half carcass of Merino wethers ranged from 0.81 to 0.99, indicating that these equations accounted for 81 % to 99 % of the variation in the carcass tissue components. However, high R^2 values indicate the prediction of weight of individual dissected tissue in Merino wether carcasses is possible.

Acknowledgement. This study was supported partially by a grant from the Agricultural Research Center, King Saud University. The authors are grateful to the staff members of the Saudi Livestock Transport and Trading Co. for their sincere help.

References

[1] Southam, G.R. and Field, R.A. "Influence of Carcass Weight Upon Carcass Composition and Consumer Preference for Lamb." *J. Anim. Sci.*, **28** (1969), 584-588.

[2] Harrison, V.L. and Crouse, J.D. "Can Feedlot Lambs be Fed Economically to Heavier Weights?" *USDA Econ. Stat.* and *Coop Serv., ESCS,* **15** (1978).

[3] Kemp, J.D., Crouse, J.D., Deweese, W. and Moody, W.G. "Effect of Slaughter Weight and Castration on Carcass Characteristics of Lambs." *J. Anim. Sci.*, **30** (1970), 348-354.

[4] Campion, D.R., Field, R.A., Riley, M.L. and Smith, G.M. "Effect of Weight on Carcass Merit of Very Heavy Market Ram Lambs." *J. Anim. Sci.*, **43** (1976), 1218-1230.

[5] Sents, A.E., Walters, L.E. and Whiteman, J.V. "Performance and Carcass Characteristics of Ram Lambs Slaughtered at Different Weights." *J. Anim. Sci.*, **55** [1982), 1360-1369.

[6] Romans, J.R., Costello, W.J., Jones, K.W., Carlson, C.W. and Ziegler, P.T. *The Meat We Eat.* Illinois: The Interstate Printers and Publishers, Inc., 1985.

[7] Abouheif, M.A., Al-Haowas, Y. and Bakkar, M.N. "Effect of Slaughter Weight on Carcass Characteristics and Cutability of Imported Merino Wethers." *J. King Saud Univ., Agric. Sci.*, **1** No. 1,2 (1989), 25-33.
[8] Steel, R.G. and Torrie, J.H. *Principles and Procedures of Statistics*. New York: McGraw-Hill book Co., 1960.
[9] SAS User's Guide. *Statistical Analysis System*, Box 8000, NC 27511, USA 1986.
[10] Palsson, H. and Verges, J.B. "Effects of the Plan of Nutrition on Growth and the Development of Carcass Quality in Lambs." *J. Agric. Sci.*, (Camb.). **42** (1952), 1-149.
[11] Beitz, D.C. "Physiological and Metabolic Systems Important to Animal Growth: An Overview." *J. Anim. Sci.*, **61** (suppl. 2) (1985), 1-20.
[12] Rouse, G.H., Topel, D.G., Vetter, R.L., Rust, R.E. and Wickershman, T.W. "Carcass Composition of Lambs at Different Stages of Development." *J. Anim. Sci.*, **31** (1970), 846-855.
[13] Lirette, A., Seoane, J. R., Minvielle, F. and Froehlich, D. "Effects of Breed and Castration on Conformation, Classification Tissue Distribution, Composition and Quality of Lamb Carcasses." *J. Anim. Sci.*, **58** (1984), 1343-1357.
[14] Butterfield, R.M., Griffiths, D.A., Thompson, J.M., Zamora, J. and James, A.M. "Changes in Body Composition Relative to Weight and Maturity in Large and Small Strains of Australian Merino Rams." *Anim. Prod.*, **36** (1983), 29-37.
[15] Lambuth, T.R., Kemp, J.D. and Glimp, H.A. "Effect of Rate of Gain and Slaughter Weight on Lamb Carcass Composition." *J. Anim. Sci.*, **30** (1970), 27-35.
[16] Jacobs, J.A., Field, R.A., Botkin, M.P., Riley, M.L. and Roehrkasse, G.P. "Effect of Weight and Castration on Lamb Carcass Composition and Quality." *J. Anim. Sci.*, **35** (1972), 926-930.
[17] Van Sickle, D.C. "Control of Postnatal Bone Growth." *J. Anim. Sci.*, **61** (suppl. 2) (1985), 76-91.
[18] Makarechian, M., Whiteman, J.V., Walters, L.E. and Munson, A.W. "Relationships between Growth Rate, Dressing Percentage and Carcass Composition in Lambs." *J. Anim. Sci.*, **46** (1978), 1610-1617.
[19] Abouheif, M.A., Alsobayel, A.A. and Mostafa, S.E. "Distribution of Lean, Fat and Bone in the Carcasses of Najdi and Naeimi Ram Lambs." *Arab Gulf J. Sci. Res., Agric. Biol. Sci.*, **B6** (1988a), 21-29.
[20] Kempster, A.J., Cuthbertson, A. and Harrington, G. *Carcass Evaluation in Livestock Breeding, Production and Marketing*. New York: Granada Publishing Lt., 1982.
[21] Abouheif, M.A., Alsobayel, A.A. and Basmaeil, S. "A Comparison of Carcass Chemical Composition of Najdi and Naeimi Ram Lambs Slaughtered at 50 kg Body Weight." *Arab Gulf J. Sci. Res., Agric. Biol. Sci.*, **B6** (1988b), 153-162.

دراسة نتائج فصل الأنسجة ومعادلات التنبؤ لمعرفة تأثير وزن الذبح على توزيع اللحم والدهن والعظام في أغنام المرينو المخصية

محمد أبوهيف، يوسف الحواس ونادر بكار

قسم الإنتاج الحيواني، كلية الزراعة، جامعة الملك سعود، الرياض، المملكة العربية السعودية

ملخص البحث. ذبح في هذه التجربة (٤٥) رأسا من أغنام المرينو المخصية والمستوردة من استراليا والتي وزعت بالتساوي على ثلاث مجموعات وزنية (٥٢، ٥٨، ٦٥ كجم) وذلك من أجل دراسة تأثير وزن الذبح على توزيع اللحم الأحمر، الدهون والعظام في القطعيات القياسية المختلفة للذبيحة.

وأوضحت النتائج أن وزن اللحم الأحمر في قطعيات الفخذ والكتف والقطن والصدر قد ازداد بصورة غير ملموسة إحصائيا عند زيادة متوسط وزن الذبح من ٥٢ إلى ٥٨ كجم، وذلك على عكس الزيادة الواضحة إحصائيا والتي شوهدت عند زيادة متوسط وزن الذبح من ٥٨ إلى ٦٥ كجم. وقد لوحظ أيضا أن وزن الدهن في القطعيات القياسية للذبيحة قد ازداد بصورة ملموسة إحصائيا كلما تزايد متوسط وزن الذبح للأغنام. ودلت النتائج أيضا أن وزن العظام في القطعيات المختلفة للذبيحة قد ازداد بمعدلات متفاوتة كلما تزايد متوسط وزن الذبح. وأوضحت دراسة معامل الارتباط أن أفضل تلك العلاقات هي التي بين أوزان اللحم الأحمر أو العظام في قطيعة الفخذ وبين إجمالي وزن الأنسجة نفسها في نصف الذبيحة المبرد، وكذلك بين وزن الدهن في قطيعة القطن وبين إجمالي وزن الدهن في نصف الذبيحة المبرد.