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PREDICTION OF LAMB CARCASS COMPOSITION & CLASSIFICATION OF CANADIAN LAMBS BY SALEABLE MEAT YIELD

BY

KIMBERLY STANFORD ©

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Prediction of lamb carcass composition and classification of Canadian lambs by saleable meat yield submitted by Kimberly Stanford. In partial fulfillment of the requirements for the degree of Doctor of Philosophy in Animal Science.

Dr. M.A. Price

Dr. L.J. McCargar

Dr. S.D.M. Jones

Dr. R.W. Purchas

Dr. F.S. Novak

Dated: 1995 March 15

DEDICATION

I would like to dedicate this thesis:

1) to my husband Tim who besides giving me love and encouragement said I would be a fool if I didn't complete a degree under the circumstances.
2) to my children Zack and Amy who missed me when ever I had to go to "versity".
3) to my co-workers: Geoff, Andy, Brian and Ray who kept the sheep research program on track while I banged away on my thesis and course work.
4) to my former boss, Don Scheer, who gave me the go ahead to proceed.
5) to my parents who were happy that someone in the family might finally complete a PhD.
6) to my cat, Velcro, who sat in my lap purring during the long hours of studying for the qualifying exam.
7) and finally, to my high-school chemistry teacher who said that I would have a PhD some day, I apologize for thinking you senile (he had also taught my mother) or otherwise demented.

ABSTRACT

The majority of north-American consumers perceive lamb as a product of low value due to its high proportion of fat and low proportion of lean. Consequently, lamb carcass composition must change to meet consumer demand for the north-American sheep industry to survive. Key to altering lamb carcass composition are methods of predicting carcass composition both *in* and *ex vivo*. Traditional, subjective *in vivo* methods limit the upstream flow of information through the lamb supply channel. As an alternative to subjective methods, *in vivo* ultrasound measurement of subcutaneous fat at the first lumbar vertebra predicted saleable meat yield with a precision (R^2 = 0.64, RSD=1.2%) comparable to the Canadian Lamb Carcass Classification System. *In vivo* methods are also required for genetic selection for improved carcass composition. Ultrasound measurement of ram and ewe lambs (n=74) from birth to 180 d of age found age was the only significant predictor ($P < 0.15$) of area, width and depth of the longissimus muscle at the first lumbar vertebra. *Ex vivo* predictions of carcass composition are required to set carcass value and determine the most appropriate end uses for the carcass. A classification scheme requiring little capital input is required for small abattoirs while an automated system is needed for large abattoirs with rapid chain speeds. A number of objective carcass measurements (carcass length, length of hind leg, depth of hind leg, circumference of hind leg) and carcass weight were able to predict saleable meat yield of lambs with precision (R^2 = 0.61, RSD=1.3 g kg^{-1}) equal to the Canadian Classification System which includes a subjective component. However, the objective system was too slow for commercial use. Collection of 93 shape and colour measurements $carcass^{-1}$ by video image analysis improved prediction of saleable meat yield by 20% (R^2=0.71, RSD=14 g kg^{-1}) compared to Canadian Classification. In conclusion, four systems for prediction of saleable meat yield (ultrasound *in vivo*

immediately prior to slaughter, ultrasound *in vivo* at age 100 d, the Canadian Classification System and video image analysis of carcasses) would allow classification and entry into the marketing channel and upstream flow of carcass composition information for all Canadian lambs.

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CHAPTER 1

GENERAL INTRODUCTION

Methods of predicting lamb carcass composition.

1.1 Introduction

The sheep industry, world wide, faces a fundamental problem. With the exception of the major lamb-exporting countries (New Zealand and Australia) and some areas of the Middle East, consumption of lamb has markedly declined over the past 30 years (Lewis et al. 1993). Although consumption of other red meats has also declined during this period, lamb consumption in North America has fallen to the point where it is difficult to even assess.

In order to reverse the downward trend in lamb consumption, the needs of the modern consumer need to be more closely addressed. As outlined by Ward et al. (1995), consumers require meat with more lean, less fat (the minimal fat level required to maintain juiciness and flavour), consistent quality, portions that are considered good value for money with minimal wastage, convenience/ease in cooking and a high level of choice/flexibility in available cuts. Unfortunately, the studies of Ward et al. (1995) and others (Harris et al. 1990; Beermann et al. 1995) have shown that lamb is currently failing to meet these consumer demands.

Before lamb carcasses can be changed to better meet consumer demand, carcasses

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must be evaluated using two equally important categories: (1) quality attributes such as tenderness, cut size, fat cover, marbling, meat and fat colour; (2) composition attributes such as saleable meat yield, or proportions of fat, lean and bone (Harrington and Kempster 1989). It is the intent of this chapter to review and evaluate methods available for prediction of body/carcass composition in sheep which may, in some cases, also allow prediction of quality attributes.

Although prediction of carcass composition in sheep has been the subject of earlier reviews (Alliston 1983; Kempster 1983; Allen 1990; Fisher 1990; Simm 1992), more recent reviews have either had a narrow focus (Russel 1995) or have excluded sheep (Forrest 1995; Jones 1995). A re-evaluation of methods for predicting carcass composition in sheep is warranted due to changes in technology since publication of the earlier reviews.

The methods of predicting carcass composition discussed in this chapter are required for a variety of purposes. Extremely rapid methods, capable of evaluating a carcass in 8 seconds or less would be relevant for on-line use (Hopkins et al. 1995), provided that damage to the commercial value of the carcass is minimal. Relatively rapid and inexpensive *in vivo* methods which do not harm animal performance would be applicable for the selection of breeding stock or estimation of market-readiness. In contrast, methods of extreme accuracy and/or precision may be useful in research applications, regardless of cost or time/labour requirements.

1.2 Body composition *in vivo*

Key to changing carcass composition to better meet consumer demand are methods of evaluating body composition *in vivo*. It is desirable that *in vivo* methods be applicable in young animals, enabling early selection of lambs with highly desirable body/carcass composition as breeding stock (Brash et al. 1992). Generally, carcass composition traits in sheep are moderately highly heritable (Simm 1992). Heritability estimates on a weight-adjusted basis for percentages of carcass lean and fat are commonly found to be 0.40 for lean and 0.45 for fat (Wolf and Smith 1983; Simm et al. 1987). Improvement in carcass composition by genetic selection is possible for traits such as fat partitioning which show a high degree of variation in individual animals within a breed (Butterfield 1988), but would be limited for other traits such as muscle weight distributions which show very small variation either within or across breeds when sheep are compared at the same stage of maturity (Kempster and Cuthbertson 1977). Ignoring genetic factors such as selection intensity which are beyond the scope of this paper, the rate of improvement would be largely dependent on the precision of the method used for estimating body/carcass composition *in vivo*. Other factors which need to be evaluated to determine the utility of methods for prediction of body and carcass composition include the cost/ease of making the predicting measurements and the stability of the prediction between animals differing in sex, breed or feeding regime (Kempster et al. 1976). A summary of selected methods for evaluation of body composition *in vivo* is shown in Table 1.1.

1.2.1 Subjective measurements

Visual appraisal in combination with condition scoring (manual assessment of fatness) is the most rapid and inexpensive method for prediction of body composition *in vivo* (Kempster 1984). However, the variation between breeds in the proportion of total fat stored subcutaneously (Fahmy et al. 1992) limits the usefulness of this method. Within breeds, trained livestock evaluators have been able to estimate lamb carcass composition with accuracies superior to that of ultrasound (Nicol and Parratt 1984; Edwards et al. 1989). Provided breed types are relatively uniform, lamb "drafters" in New Zealand use visual appraisal/condition scoring for prediction of carcass composition with accuracies approaching those of ultrasound (Dodd et al. 1986). However, the small number of suitably experienced/proficient personnel in countries other than New Zealand and difficulties in maintaining standards across time and geographical regions would limit the usefulness of subjective estimates of body composition.

1.2.2 Liveweight

In vivo techniques commonly use liveweight as the standard to which other predictors of body composition are compared (Kempster 1984, Simm 1992) although live weight may be difficult to accurately measure due to the influence of gut fill and fleece length/hydration. As outlined by Butterfield (1988), tissues within the body follow predictable patterns of development from birth to maturity. The proportion of muscle in sheep compared at fleece-free empty body weights has been shown to be relatively uniform, ranging from 28% (McClelland et al. 1976) to 30% (Thonney et al. 1987). The currently reported exceptions to this general rule are the Soay and Texel breeds, the Soay having less fat and more bone (McClelland et al. 1976) and the Texel having less fat and more lean than would be expected. The usefulness of liveweight as a predictor of body composition is limited by difficulties in assessing an animal's stage of maturity which can be influenced by genotype, nutrition, disease, physical environment, level of activity, social environment and age (Taylor 1965). In lambs of equal maturity (same age and breed), liveweight predicted % carcass lean with a residual standard deviation (RSD) ranging from 1.4 (Cuthbertson et al. 1984) to 2.2 (Fortin and Shrestha 1986), with R^2 values of 0.51 and 0.76, respectively. When lambs were of differing maturity (varying ages, multiple breeds) liveweight has been less useful for predicting % carcass fat (RSD of 3.9 Purchas and Beach 1981).

1.2.3 External linear Measurements

Prior to development of technologies enabling *in vivo* prediction of carcass composition, a number of linear measurements (shoulder height, heart girth, body length ...) were evaluated as predictors of body composition in live sheep (Orme et al. 1962; Orme 1963; Cunningham et al. 1967), but were found to be of marginal utility in lambs of varying age, sex or breed type. Although the use of linear measurements has been periodically re-investigated (Cuthbertson et al. 1984; Edwards et al. 1989), the inability of linear measurements to distinguish between lean and fat would limit their application as primary predictors of body composition to goats and certain breeds of sheep which have limited subcutaneous fat stores. The utility of linear measurements has also been reduced by the accuracy to which the measurements may be recorded. Most studies have used either callipers or measuring tapes, leading to increased error due to animal movement and variations in fleece cover.

1 2.4 Ultrasound

Ultrasound equipment converts electrical pulses to high-frequency sound waves which are reflected from the boundaries between tissues of different bioacoustic densities (Houghton and Turlington 1992). Two types of ultrasound equipment are used: A-mode machines, available since the 1950's, which measure echo amplitude against time, with the distance between echoes being related to the distance between successive tissue interfaces (Simm 1983); B-mode or real-time machines developed in the early 1980's, where "grey-scales" measure echo intensity in a two-dimensional scan (Stouffer 1988). The velocity of ultrasound through soft tissues is also used to predict body composition (Miles et al. 1991), offering the advantage of absolute values instead of images requiring subjective interpretation.

Early studies reported that ultrasound was either of little (Jones et al. 1982; Hamby et al.

1986) or no use (Leymaster et al. 1985, Fortin and Shrestha 1986; Edwards et al. 1989) for predicting body/carcass composition in sheep. The limited utility of ultrasound was attributed to the small size and lack of variation in subcutaneous fat thickness and longissimus muscle area in sheep as compared to cattle and pigs (Houghton and Turlington 1992). Purchas and Beach (1981) attributed the reduced utility of ultrasound in sheep to a soft, mobile subcutaneous fat layer, with wool an added complicating factor. However, the use of ultrasonic measurements of backfat and longissimus muscle depth ('C' and 'B' measurements, respectively of Pálsson 1939) at the third lumbar vertebra has been shown to improve the rate of genetic selection for carcass fatness by 10.3% and carcass grade (muscling and fatness) by 14.5%, compared to selection based on liveweight alone (Olesen and Husabø 1994).

Regardless of the precision of ultrasound methods, sheep body composition has been significantly improved after 3-4 yr of selection using indexes based on ultrasonically measured backfat, muscle depth and liveweight (Cameron and Bracken 1992; Simm et al. 1993). Additionally, the relatively low cost and ease of portability of ultrasound equipment has led to incorporation of ultrasound measurements into national genetic programs for lamb carcass quality improvement in many parts of the world (Table 1.2).

1.2.5 X-ray computed tomography

Unlike ultrasound which was first used for military purposes, the equipment used in x-ray computed tomography (CT) was first developed for human medicine (Vangen 1989). An x-ray generator and x-ray detectors are rotated around the subject, firing pulses of radiation and measuring the amount of radiation transmitted through the subject (Simm 1992). The rate of attenuation of the x-rays allows computerized calculation of densities in a cross section of the subject, the densities being standard values which vary from -1000 for air to

+1000 for bone (Standal 1984). *In vivo* use of CT is applicable only for smaller livestock such as sheep, goats, chickens and pigs due to the human-scale of the equipment (Vangen 1989).

Although studies where CT has been used for prediction of body composition in sheep are limited, Sehested (1984) reported that CT values with live weight could predict kg fat-free lean in lambs with R^2 values of 0.92 to 0.94, RSD 0.5 to 0.6, compared to prediction with liveweight alone (R^2 = 0.83, RSD = 0.8). Jopson et al. (1995) reported that compared to ultrasound, CT would double the rate of genetic improvement for lean meat traits in lambs as direct selection was possible for protein content and proportions of lean, intermuscular and intramuscular fat. However, the ten-fold higher cost of CT (equipment and operating expenses) as compared to ultrasound (Parratt and Simm 1987) will likely result in general use of ultrasound for evaluation of body composition in sheep, with CT reserved for a select group of the most promising rams. X-ray CT has been used for evaluation of elite rams in the U.K. (Simm 1992) and Australia (Jopson et al. 1995). Recently CT equipment was also purchased in New Zealand for a commercial scanning service (Innervision) for high-value sheep (Davis and Fennessy 1996).

1.2.6 Nuclear Magnetic Resonance / Magnetic Resonance Imaging

A nuclear magnetic resonance (NMR) machine consists of an electromagnet with a central opening large enough for a human. The strong magnetic field tends to induce resonance of protons in the subject (Wells 1984). The time needed for the protons to re-establish original conditions has been defined as spin-lattice relaxation time T1 and spin-spin relaxation time T2 (Groeneveld et al. 1984) which differ depending on factors such as the state of hydration or fat content of a tissue (Simm 1992). Contrary to CT, there are no standardized values in NMR due to changes in conditions and parameters between measurements (Groeneveld et al. 1989). However, NMR has additional capabilities compared to CT, including evaluation of muscle metabolism and prediction of carcass quality attributes such as water-holding capacity (Monin and Renou 1989). Spectroscopy and magnetic resonance imaging are discrete types of NMR, although both are applicable to the prediction of body composition (Simm 1992).

The accuracy of NMR at predicting body composition is thought to be superior to that of CT (Groeneveld et al. 1984; Simm 1992), although CT and NMR were found to be of equal value in determining adipose tissue volumes of rats (Ross et al. 1991). High operating costs for NMR, estimated to be equivalent to the wages of 20 research staff (Pedersen 1989), have restricted access to NMR equipment for livestock species to a larger extent than access to CT. In the sole study where NMR has been used to evaluate body composition in sheep, Streitz et al. (1995) reported R^2 values ranging from 0.78 to 0.91 for percentage of lean in lambs at body weights from 10 to 50 kg. Presently, programs using NMR for the genetic improvement of carcass quality in livestock are restricted to poultry (Mitchell et al. 1991; Liu et al. 1994). Additional studies with sheep would be required before the benefits of using NMR for prediction of body composition could be evaluated relative to costs.

1 2.7 Other methods for in vivo prediction of body composition

Other techniques for prediction of body composition presently used in human medicine include dual-photon absorptiometry (Mazess et al. 1990); dual x-ray absorptiometry (Dalsky et al. 1990) and underwater weighing (Wang et al. 1989). However, underwater weighing would be practical only for sheep carcasses. Additionally, radionucleotides are costly and their use in meat animals would be a perceived human health concern. Dilution techniques for estimating body water using radionucleotides (Robelin and Theriez 1981) and urea (Jones et al. 1982) have been used to predict body composition of sheep, but due to the length of time required (up to 48 h animal^{-1}) and the amount of labour involved, are applicable only in research studies (Robelin 1984). Discussions of total body electrical conductivity (TOBEC) and bioelectrical impedance analysis (BIA) are presented in Sections 1. 3.6 and 1. 3.7, respectively.

1.3 Carcass composition *ex vivo*

Carcass composition assessment serves three functions: (1) assigns carcass value; (2) allows sorting of carcasses for further processing or fresh meat merchandising; (3) transfers information back to the production sector, hopefully ensuring that carcasses meet consumer demand. As with *in vivo* methods, it is desirable that methods of assessing carcass composition *ex vivo* be precise, accurate over time and distance and across lambs of varying breeds, sexes and ages. However, cost, ease of measurement and speed of methods are crucial. Highly precise methods such as NMR and CT would be too slow for on-line use (Forrest 1995), even if they were cost effective. Other methods, such as dissection of small regions of the carcass (Timon and Bichard 1965; Kempster et al. 1976), while precise and requiring little expenditure for capital equipment, would be slow, labour-intensive and result in reduced carcass marketability/value. A summary of currently available inexpensive manual, non-destructive methods of carcass evaluation *ex vivo* is shown in Table 1.3, while methods requiring more sophisticated equipment are shown in Table 1.4.

1.3.1 Subjective measurements

Lamb carcass composition is commercially evaluated in many countries (Australia, USA, South Africa, UK) by subjective assessment of fatness or conformation (Jones et al. 1992). Even in New Zealand where a system for objective measurement is in place, body composition/fatness of lambs is usually subjectively evaluated (Kirton et al. 1992). Conformation and fatness are related, as lamb carcasses with good conformation are generally fatter than those with poor conformation (Kirton and Pickering 1967; Kempster et al. 1981). The only exceptions to this are well-muscled animals within a breed, breeds such as the Texel (Kempster et al. 1987; Leymaster and Jenkins 1993) or genetic mutations such as the Callipyge (Busboom et al. 1996).

The utility of subjective methods for evaluating carcass composition has been largely dependent on the population of lambs evaluated. When lambs have been of varying breed types, ages or sizes, subjective assessments have been useful predictors of carcass composition (Kirton et al. 1992; Jones et al. 1993), but have had little utility in more uniform lamb populations (Kempster et al. 1981; Horgan et al. 1995). However, even in highly diverse lamb populations, subjective evaluations alone have been marginal predictors of carcass composition (R^2 = 0.61, RSD = 1.71% for the best equation including GR measurement and subjective conformation predicting saleable meat yield vs R^2 = 0.55, RSD = 1.84% for the same equation excluding conformation; Jones et al. 1993). A global change to objective evaluation and more precise methods for assessing lamb carcass composition would be the first step in identifying and rewarding production of the lean yet well-muscled lamb needed to meet consumer demand.

1.3.2 Carcass weight, specific gravity and dressing percentage

Fat has a lower density than other carcass components and the determination of carcass specific gravity (weight in air/(weight in air - weight underwater)) was the subject of early investigations (Kirton and Barton 1958; Timon and Bichard 1965). In these studies, carcass specific gravity was found to be equal to dressing percentage (hot carcass weight/live weight) as a predictor of carcass fat content, although specific gravity was not deemed sufficiently accurate for individual carcass determination due to a high RSD (2.98 to 3.2 for % carcass fat) and its reduced accuracy at lower levels of fatness. Comparing carcass weight, specific gravity and dressing percentage, Barton and Kirton (1958) found carcass weight to be the superior predictor of carcass fat content in sheep as it was not subject to as many errors in measurement as was specific gravity and was not influenced by variations in gut fill as was dressing percentage. More recently, Kirton et al. (1985) reported that although the New Zealand lamb grading system was based on hot carcass weight (HCW), adding HCW into a regression after Grade Rule (GR) (Kirton and Johnson, 1979) was in the model did not increase R^2 for any measure of carcass composition by more than 0.03. Similarly, Jones et al. (1993) reported that HCW was not a significant predictor of saleable meat yield in lambs. However, lamb carcasses are routinely valued based on HCW and HCW is available with limited expense. Accordingly, use of carcass composition predictors other than HCW are warranted only if they improve the accuracy of prediction compared to use of HCW alone.

1.3.3 Linear Measurements - GR and others

Many attempts have been made to find rapid, inexpensive and accurate methods of estimating carcass composition from carcass dimensions and fat or muscle depths at various locations on the lamb carcass (Pálsson 1939; Timon and Bichard 1965; Kirton and Johnson 1979; Bennett et al. 1988). However, there is not one ideal measurement or set of measurements. Some measurements primarily identify carcass composition differences associated with factors such as sex, breed or weight and are useful in heterogenous populations, although the same measurements may be less useful for discriminating among uniform populations of sheep (Bennett et al. 1988).

Pálsson (1939) was first to identify a number of sheep carcass measurements, some of which remain in use today. These include 'A', the maximum width of the longissimus muscle; 'B', the maximum depth of the longissimus muscle measured at right angles to 'A'; 'C', the depth of backfat over 'B'; 'J' the greatest depth of subcutaneous fat over the rib. Carcasses must be cut to determine these measurements, unless advanced imaging technologies are employed. Currently, many national ultrasound programs for lamb carcass quality improvement utilize 'C' and/or 'B' at various locations on the carcass (Table 1.2). Pálsson (1939) also described numerous external carcass dimensions including carcass length 'L', length of the leg 'T' and depth of the leg 'H'. However, Kempster (1981) concluded that carcass dimensions are poor individual predictors of carcass composition, a finding supported by Bennett et al. (1988).

GR is a measurement of total soft tissue thickness between the outside surface of a lamb carcass and the 12th rib at a point 11 cm from carcass mid-line (Kirton and Johnson 1979). GR can be measured in intact carcasses by use of a sharpened metal ruler (Kirton et al. 1984) or by a variety of probes, the probes measuring tissue thickness between the ribs (Jones et al. 1992; Hopkins et al. 1995; Kirton et al. 1995). GR has been shown to explain 40 to 76% and 44 to 72% of the variation in carcass fat and lean, respectively (Kirton et al. 1985; Jones et al. 1992). Comparing GR to other carcass measurements, Kirton and Johnson (1979) reported that GR was as accurate as 'C' for prediction of carcass fat. The superiority of GR over longissimus muscle area and 'B' for prediction of carcass composition was confirmed by Jones et al. (1992) in accord with Kempster (1981) who concluded that area and depth of the longissimus muscle were of limited value in prediction of lamb carcass composition.

1.3.4 Mechanical and Optical Probes

Mechanical and optical probes objectively measure fat and muscle depths and are routinely used to measure GR according to New Zealand export lamb grading regulations (Price 1995). Optical probes consist of a light-emitting diode which illuminates the meat from under an optical window. Detectors respond to an increase in reflected light when the optical window passes from muscle to fat as the probe is withdrawn from the carcass (Swatland 1995). As reported by Kirton et al. (1995), probes currently available for prediction of lamb carcass composition include the Hennessy Grading Probe (Hennessy Grading Systems Ltd., Auckland, NZ), the AUS-Meat Sheep Probe (SASTEK, Hamilton, Queensland, Australia), the Swedish FTC lamb probe (FTC Sweden, Upplands, Väsby, Sweden) and the Ruakura GR Lamb Probe (Hamilton, NZ). Only the AUS-Meat probe is capable of functioning at chain speeds of 9 to 10 carcasses per minute (Cabassi 1990; Hopkins et al. 1995). On warm carcasses, optical probes have predicted GR with accuracy equivalent to a manual GR knife/ruler (Jones et al. 1992; Hopkins et al. 1995). In a comparison of all commercially available optical probes (Kirton et al. 1995), manual GR probes on chilled carcasses were found to account for a higher percentage of variation in carcass fat content (59%) than optical probes on hot carcasses (49%). However, the increased accuracy of manual as compared to optical probes in the study of Kirton et al. (1995) is likely due to improvements in the accuracy of prediction of carcass composition in cold as compared to warm carcasses as noted by Chadwick and Kempster (1983) and Jones et al. (1992).

1 3.5 Video Image Analysis

Where time and labour requirements restrict, usually to one, the number of manual or optical probe measurements that can be made under commercial conditions, video image analysis (VIA) allows for the automated collection of multiple carcass dimension and colour measurements (Jones et al. 1995). Wood et al. (1991) described VIA as a system capable of objectively measuring carcass conformation, with equipment including a video camera, controlled lighting of the carcass and computer/software necessary to digitize the video image. Although evaluations of VIA for prediction of carcass composition in lambs are limited, early indications as to its utility are promising. In lambs of uniform age and breed, Horgan et al. (1995) reported that VIA shape variables for cold carcasses, carcass weight and sex could predict saleable meat yield with greater accuracy (R^2 = 0.16, RSD = 0.89 %) than carcass weight, sex and the current subjective system used in the UK (R^2 = 0.04, RSD = 0.95 kg). As the VIA equipment required for evaluation of lamb carcasses is approximately equal in value to the yearly wages of a livestock grader, VIA shows potential as an objective, accurate, yet cost-effective method of evaluation of lamb carcass composition.

1.3.6 Total Body Electrical Conductivity (TOBEC)

Lean tissue is approximately 20 times more conductive of electricity than fat or bone because of higher concentrations of water and electrolytes (Funk 1991). Based on this principle, carcasses passed through an electromagnetic coil generate a relative energy absorption curve. Areas under parts of the curve and differences between positions on the curve are therefore related to lean mass (Swatland 1995). Although this technology has been used on live pigs (EMME electronic meat measuring equipment, EMME Corp, Phoenix, AZ), movement of the pigs led to inaccurate estimates of lean content (Forrest et al. 1991). Using TOBEC (Meat Quality Inc., Springfield IL), electrical conductivity measurements and carcass length were able to predict % carcass lean in lambs with a reasonable degree of accuracy (R^2 = 0.78, RSD = 1.71%), although carcass position within the scanner, carcass temperature and geometric orientation of the carcass were recognized as sources of error (Berg et al. 1994). As carcass geometry and temperature cannot always be controlled, TOBEC technology is currently most applicable to evaluation of lean content in boxed meat (Eustace and Thorton 1991) and in pig carcasses (Gu et al. 1992) which have less variation in inter/intramuscular fat content and size/shape than beef or lamb carcasses.

1.3.7 Bioelectrical impedance analysis (BIA)

Another method dependent on transmission of electric current through a carcass, bioelectrical impedance measures are related to conductor length, cross-sectional area and signal frequency; leading to the hypothesis that a fat lamb should impede the transmission of electrical current to a larger extent than a lean lamb (Berg et al. 1996). Two pairs of transmitter and detector electrodes (21 gauge needles) are located in an anterior to posterior sequence along the full length of the animal's back (Swatland 1995). Impedance measurements include resistance and reactance which are calculated by transmitting alternating current between the outer two electrodes and measuring the voltage drop between the inner two detector electrodes (Berg and Marchello 1994). For lamb carcasses, Jenkins et al. (1988) reported that carcass weight and resistance accounted for 93.6% of the variation in fat-free soft tissue, although carcass weight alone accounted for 91.1% of the variability. For live lambs, Berg et al. (1996) concluded that bioelectrical impedance measurements along with body length and live weight did not predict proportional carcass yield with a high degree of accuracy (R^2 = 0.296, RSD = 2.53, for % boneless closely trimmed primal cuts). An advantage to bioelectrical impedance is that measurements can be made in live animals as well as carcasses (Berg and Marchello 1994; Berg et al. 1996), although the invasiveness of the procedure as well as its low precision would not favourably compare to other relatively inexpensive *in vivo* methods such as ultrasound.

1.4 Conclusions

As part of the impetus to meet consumer demand and increase consumption of lamb, a change has to be made from subjective to objective evaluation of body and carcass composition. Even though subjective methods are the most rapid and inexpensive techniques for evaluation of body and carcass composition, the sheep industry, if it is to survive in the long-term, can no longer afford the error inherent in subjective predictions. Continuance of traditional, subjective methods for evaluation of body and carcass composition, will not reverse the current decline in lamb consumption compared to other meats.

In live sheep, the high cost/limited access of some of the more precise methods for evaluation of body composition such as X-ray CT or NMR will make ultrasound the method of choice, despite its relatively low precision. In countries where the size of the sheep industry warrants greater capital expenditure by private industry, methods such as X-ray CT, NMR or others are or will likely become available for selection of breeding stock.

Development of improved methods for carcass composition evaluation is of little utility unless these methods are eventually adopted by the meat industry. Even in New Zealand, the global leader in lamb merchandising, GR measurements are usually made subjectively due to high slaughter-chain speeds. Where wholly subjective methods are currently used, adoption of an objective measurement such as GR would be a first step towards more precise evaluation of lamb carcasses. The next step would be use of methods with higher precision than GR such as VIA, with added advantages of use on-line on warm carcasses, facilitating the early channelling of carcasses to their most profitable and/or consumer-desired endpoints.

1.5 Subsequent chapters of this thesis

After reviewing the various methods available for the prediction of body and carcass composition in sheep in this introduction, Chapter Two of the thesis seek to describe the Canadian sheep industry, the role of grading in lamb marketing and the results of a survey of Canadian abattoirs as to their preferred methods of buying lambs. Chapters Three through Six of the thesis outline experiments conducted with selected methods for the prediction of carcass composition *in* or *ex vivo*. Finally, Chapter Seven offers a general discussion and conclusions based on all thesis material.

1.6 References

Allen, P., 1990. New approaches to measuring body composition in live meat animals. In: J.D. Wood and A.V. Fisher (Editor), Reducing Fat in Meat Animals. Elsevier, London, UK, pp. 201-247.

Alliston, J.C., 1980. Evaluation of carcass quality in the live animal. In: W. Haresign (Editor), Sheep Production. Butterworths, London, UK, pp. 75-96.

Atkins, K.D., Murray, J.I., Gilmour, A.R. and Luff, A.L., 1991. Genetic variation in liveweight and ultrasonic fat depth in Australian Poll Dorset Sheep. Aust. J. Agric. Res., **42:** 629-640.

Barton, R.A. and Kirton, A.H., 1958. Carcass weight as an index of carcass components with particular reference to fat. J. Agric. Sci., **50:** 331-334.

Beermann, D.H., Robinson, T.F. and Hogue, D.E., 1995. Impact of composition manipulation on lean lamb production in the United States. J. Anim. Sci., **73:** 2493-2502.

Bennett, G.L., Meyer, H.H. and Kirton, A.H., 1988. Effect of average carcass fat concentration on correlations among lamb carcass measurements. Anim. Prod.. **47:** 369-377.

Berg, E.P. and Marchello, M.J., 1994. Bioelectrical impedance analysis for the prediction of fat-free mass in lambs and lamb carcasses. J. Anim Sci., **72:** 322-329.

Berg, E.P., Forrest, J.C., Thomas, D.L., Nusbaum, N. and Kauffman, R.G., 1994. Electromagnetic scanning to predict lamb carcass composition. J. Anim. Sci., **72:** 1728-1736.

Berg, E.P., Neary, M.K., Forrest, J.C., Thomas, D.L. and Kauffman, R.G., 1996. Assessment of lamb carcass composition from live animal measurement of bioelectrical impedance or ultrasonic tissue depths. J. Anim. Sci., **74:** 2672-2678.

Brash, L.D., Forgarty, N.M., Gilmour A.R. and Luff, A.F., 1992. Genetic parameters for live weight and ultrasonic fat depth in Australian meat and dual purpose sheep breeds. Aust. J. Agric. Res., **43:** 831-841.

Busboom, J.R., Snowder, G.D. and Cockett, N.E., 1996. Synopsis of the heavy muscled (Callipyge) lamb symposium. February 15th and 16th, Salt Lake City, UT.

Butterfield, R., 1988. New Concepts of Sheep Growth. Griffin Press, Australia, 168 pp.

Cabassi, P., 1990. The prediction of lamb carcase composition from objective measurements of fatness taken at slaughter chain speed with the Aus-Meat Sheep Probe. Proc. Aust. Soc. Anim. Prod., **18:** 164-167.

Cameron, N.D. and Smith, C., 1985. Estimation of carcass leanness in young rams. Anim. Prod., **40:** 303-308.

Cameron, N.D. and Bracken, J., 1992. Selection for carcass lean content in a terminal sire breed of sheep. Anim. Prod., **54:** 379-388.

Chadwick, J.P. and Kempster, A.J., 1983. The estimation of beef carcass composition from subcutaneous fat measurements taken on the intact side using different probing instruments. J. Agric. Sci., **101:** 241-248.

Cunningham, N.L., Carpenter, Z.L., King, G.T., Butler, O.D. and Shelton, J.M., 1967. Relationship of linear measurements and certain carcass characteristics to retail value, quality and tenderness of ewe, wether, and ram lambs. J. Anim. Sci., **26:** 683-687.

Cuthbertson, A., Croston, D. and Jones, D.W., 1984. *In vivo* estimation of lamb carcass composition and lean tissue growth rate. In: *In Vivo* Measurement of Body Composition in Meat Animals, D. Lister (Editor), Elsevier, London, pp. 163-166.

Dalsky, G.P., Kraemer, W., Zetterlund, A.E., Conroy, B., Fry, A., Judge J.O., Smith, J., 1990. A comparison of methods to assess body composition. Proc. Am. College of Sports

Med. Salt Lake City, UT, May 22-25.

Davis, G.H. and Fennessy, P.F., 1996. The organisation of the sheep industry in New Zealand. Proc. Int. Symp. on the Sheep Industry, October 11-12, Sherbrooke, Quebec, pp. 37-46.

Dodd, C.J., Purchas, R.W. and Bennett, G.L., 1986. Lean lamb selection, a manual of procedures. MAF Advisory Services Division, Wellington, New Zealand.

Edwards, J.W., Cannell, R.C., Garrett, R.P., Savell, J.W., Cross, H.R. and Longnecker, M.T., 1989. Using ultrasound, linear measurements and live fat thickness estimates to determine the carcass composition of market lambs. J. Anim. Sci., **67**:3322-3330.

Eustace, I.J. and Thornton, R.F., 1991. Electromagnetic scanning: evaluation of cartoned meat. Proc. Symp. Electronic Evaluation of Meat in Support of Value-Based Marketing. March 27-28, Purdue Univ., West Lafayette, IN. pp 113-122.

Fahmy, M.H., Boucher, J.M., Poste, L.M., Gregoire, R. And Comeau, J.E., 1992. Feed efficiency, carcass characteristics and sensory quality of lambs with or without prolific ancestry fed diets with different protein supplements. J. Anim. Sci., **70**: 1365-1374.

Fisher, A.V., 1990. New approaches to measuring fat in the carcasses of meat animals. In: J.D. Wood and A.V. Fisher (Editors), Reducing Fat in Meat Animals. Elsevier, London, UK, pp. 255-335.

Forrest, J.C., Kuei, C.H., Chen, W., Lin, R.S., Schinckel, A.P., Walstra, P., Kooper, H. and Judge, M.D., 1991. Electromagnetic scanning: carcass evaluation. Proc. Symp. Electronic Evaluation of Meat in Support of Value-Based Marketing. March 27-28, Purdue Univ., West Lafayette, IN, pp. 85-112.

Forrest, J.C., 1995. New techniques for estimation of carcass composition. In: S.D. Morgan Jones, ed. Quality and Grading of Carcasses of Meat Animals, pp. 157-172.CRC

Press, Boca Raton.

Fortin, A. and Shrestha, J.N.B., 1986. *In vivo* estimation of carcass meat by ultrasound in ram lambs slaughtered at average live weight of 37 kg. Anim. Prod., **43:** 469-475.

Funk. R., 1991. Electromagnetic scanning: basis and recent advances in technology. Proc. Symp. Electronic Evaluation of Meat in Support of Value-Based Marketing. March 27-28, Purdue Univ., West Lafayette, IN, pp. 73-84.

Groeneveld, E., Kallweit, E. Henning, M and Pfau, A., 1984. Evaluation of body composition of live animals by x-ray and nuclear magnetic resonance computed tomography. In: D. Lister (Editor), *In Vivo* Measurement of Body Composition in Meat Animals, Elsevier, London,pp. 84-89.

Groeneveld, E. Henning, M. and Kallweit, E., 1989. Growth patterns and carcass evaluation in pigs NMR measurements. In: E. Kallweit, M. Henning and E. Groeneveld (Editor), Application of NMR techniques on the body composition of live animals, Elsevier, New York. pp. 137-148.

Gu, Y., Schinckel, A.P., Martin, T.G., Forrest, J.C., Kuei, C.H. and Watkins, L.E., 1992. Genotype and treatment biases in estimation of carcass lean of swine. J. Anim. Sci.,**70:** 1708-1718.

Hamby, P.L., Stouffer, J.R. and Smith, S.B., 1986. Muscle metabolism and real-time ultrasound measurement of muscle and subcutaneous adipose tissue growth in lambs fed diets containing a beta-agonist. J. Anim. Sci., **63:** 1410-1417.

Harrington, G. and Kempster, A.J., 1989. Improving lamb carcass composition to meet modern consumer demand. In: O.R. Dyrmundsson and S.Thorgeirsson (Editor), Reproduction, Growth and Nutrition in Sheep , Agricultural Research Inst., Reykjavik, Iceland. pp. 79-90.

Harris, J.J., Savell, J.W., Miller, R.K., Hale, D.S., Griffin, D.B., Beasley, L.C. and Cross, H.R., 1990. A national market basket survey for lamb. J. Food Quality, **13:** 453-465.

Hopkins, D.L., Anderson, M.A., Morgan, J.E. and Hall, D.G., 1995. A probe to measure GR in lamb carcasses at chain speed. Meat Sci., **39:** 159-165.

Horgan, G.W., Murphy, S.V. and Simm, G., 1995. Automatic assessment of sheep carcasses by image analysis. Anim. Sci., **60:** 197-202.

Houghton, P.L. and Turlington, L.M., 1992. Application of ultrasound for feeding and finishing animals: a review. J. Anim. Sci., **70:** 930-941.

Jenkins, T.G., Leymaster, K.A. and Turlington, L.M., 1988. Estimation of fat-free soft tissue in lamb carcasses by use of carcass and resistive impedance measurements. J. Anim. Sci., **66:** 2174-2179.

Jensen, N.E., 1990. Performance tests of ram lambs 1990. Report 684, National Institute of Animal Science, Denmark, pp. 44.

Jones, S.D.M., Walton, J.S., Wilton, J.W. and Szkotnicki, J.E., 1982. The use of urea dilution and ultrasonic backfat thickness to predict the carcass composition of live lambs and cattle. Can. J. Anim. Sci., **69:** 641-648

Jones, S.D.M., Jeremiah, L.E., Tong, A.K.W., Robertson, W.M. and Gibson, L.L., 1992. Estimation of lamb carcass composition using an electronic probe, a visual scoring system and carcass measurements. Can. J. Anim. Sci., **72:** 237-244.

Jones, S.D.M., Robertson, W.M. and Price, M.A., 1993. The assessment of saleable meat yield in lamb carcasses. Int. Congr. Meat Sci. Technol. Calgary, AB. p 190 (Abstr.).

Jones, S.D.M., Richmond, R.J. and Robertson, W.M., 1995. Instrument beef grading. Meat Focus Intl., **4:** 59-62.

Jones, S.D.M., 1995. Future directions for carcass assessment. In: S.D.M. Jones (Editor), Quality and grading of carcasses of meat animals. CRC Press, Boca Raton, USA, pp. 215-228.

Jopson, N.B., McEwan, J.C., Dodds, K.G. and Young, M.J., 1995. Economic benefits of including computed tomography measurements in sheep breeding programmes. Proc. Aust. Assoc. of Anim. Breeding and Genetics, **11**:194-197.

Kempster, A.J., Avis, P.R., Cuthbertson, A. and Harrington, G., 1976. Prediction of lean content of lamb carcasses of different breed types. J. Agric. Sci. Camb., **86:** 23-34.

Kempster, A.J. and Cuthbertson, A., 1977. A survey of the carcass characteristics of the main types of British lamb. Anim. Prod., **25:** 165-179.

Kempster, A.J., 1980. Carcass quality and its measurement in sheep. In: W. Haresign (Editor), Sheep Production. Butterworths, London, UK, pp. 59-74.

Kempster, A.J., 1981. The indirect evaluation of sheep carcass composition in breeding scheme population studies and experiments. Livestock Prod. Sci., **8**:263-271.

Kempster, A.J., Croston, D. And Jones, D.W., 1981. Value of conformation as an indicator of sheep carcass lean content within and between breeds. Anim. Prod., **33:** 39-49.

Kempster, A.J., 1984. Cost-benefit analysis of *in vivo* estimates of body composition in meat animals. In: D. Lister (Editor), *In vivo* measurement of body composition in meat animals, Elsevier, New York. pp. 191-203.

Kempster, A.J., Jones, D.W. and Wolf, B.T., 1986. A comparison of alternative methods for predicting the carcass composition of crossbred lambs of different breeds and crosses. Meat Sci., **18:** 89-110.

Kempster, A.J., Croston, D., Guy, D.R. and Jones, D.W., 1987. Growth and carcass characteristics of crossbred lambs by ten sire breeds compared at the same estimated carcass subcutaneous fat proportion. Anim. Prod., **44:** 194-201.

Kirton, A.H. and Barton, R.A., 1958. Specific gravity as an index of the fat content of mutton carcasses and various joints. N.Z. J. Agric. Res., **1**: 633-641.

Kirton, A.H. and Pickering, P.S., 1967. Factors associated with difference in carcass conformation in lambs. N.Z. J. Agr. Res., **10**: 183-200.

Kirton A.H., and Johnson, D.L., 1979. Interrelationship between GR and other lamb carcass fatness measurements. Proc. N.Z. Soc. Anim. Prod., **39**: 194-201.

Kirton, A.H., Woods, E.G. and Duganzich, D.M., 1984. Predicting the fatness of lamb carcasses from carcass wall thickness measured by ruler or by a total depth indicator (TDI) probe. Livestock Prod. Sci., **11**:185-194.

Kirton, A.H., Duganzich, D.M., Feist, C.L., Bennett, G.L. and Woods, E.G., 1985. Prediction of lamb carcass composition from GR and carcass weight. Proc. N.Z. Soc. Anim. Prod., **45**: 63-65.

Kirton, A.H., Mercer, G.J.K. and Duganzich, D.M., 1992. A comparison between subjective and objective (carcass weight plus GR or the Hennessy Grading Probe) methods for classifying lamb carcasses. Proc. N.Z. Soc. Anim. Prod., **52**: 41-44.

Kirton. A.H., Mercer, G.J.K., Duganzich, D.M., Uljee, A.E., 1995. Use of electronic probes for classifying lamb carcasses. Meat Sci., **39**: 167-176.

Lewis, R.M., Simm, G. and Warkup, C.C., 1993. Enjoying the taste of lamb. Meat Focus Intl., **2**: 393-395.

Leymaster, K.A., Mersmann, H.J. and Jenkins, T.G., 1985. Prediction of the chemical composition of sheep by use of ultrasound. J. Anim. Sci., **61**: 165-172.

Leymaster, K.A. and Jenkins. T.G., 1993. Comparison of Texel- and Suffolk-sired crossbred lambs for survival, growth and compositional traits. J. Anim. Sci., **71**: 859-869.

Liu, Z., Lirette, A., Fairfull, R.W., McBride, B.W., 1994. Embryonic adenosine triphosphate: phosphate diesters ratios obtained with *in vivo* nuclear magnetic resonance spectroscopy (Phosphorus-31): a new technique for selecting leaner broiler chickens. Poultry Sci., **73:** 1633-1641.

Mazess, R.B., Barden, H.S., Olrich, E.R., 1990. Skeletal and body composition effects of anorexia nervosa. Am. J. Clin. Nutr., **52:** 438-441.

McClelland, T.H., Bonaiti, B. And Taylor, C.S., 1976. Breed differences in body composition of equally mature sheep. Anim. Prod., **23:** 281-293.

Miles, C.A., Fursey, G.A.J., Fisher, A.V. and Page, S.J., 1991. Estimation of lamb carcass composition from measurements of the speed of ultrasound in the soft tissues of live animals and carcasses. Meat Sci., **30:** 245-256.

Mitchell, A.D. Wang, P.C. Rosebrough, R.W. Elsasser, T.H. Schmidt, W.F., 1991. Assessment of body composition of poultry by nuclear magnetic resonance imaging and spectroscopy. Poultry Sci., **70:** 2494-2500.

Monin, G. and Renou, J.P., 1989. Spectroscopy and meat quality. In: Application of NMR techniques on the body composition of live animals, E. Kallweit, M. Henning and E. Groeneveld eds. Elsevier, New York, pp. 121-133.

Nicol, A.M. and Parratt, A.C., 1984. Methods of ranking two-toothed rams for fat-free carcass growth rate. Proc. N.Z. Soc. of Anim. Prod., **44:** 253-259.

Olesen, I. and Husabø, J.O., 1994. Effect of using ultrasonic muscle depth and fat depth on the accuracy of predicted phenotypic and genetic values of carcass traits on live ram lambs. Acta Agric. Scand., Sect. A. Animal Sci., **44:** 65-72.

Orme, L.E., Christian, R.E. and Bell, T.D., 1962. Live animal and carcass indicies for estimating the carcass composition in lambs. J. Anim. Sci., **21:** 666 (Abstr.).

Orme, L.E., 1963. Estimating composition from linear measurements, live probe and body weight. Ann. N.Y. Acad. Sci., **110:** 307-310.

Pálsson, H., 1939. Meat qualities in the sheep with special reference to Scottish breeds and crosses. J. Agr. Sci., **29:** 544-625.

Parratt, A.C. and Simm, G., 1987. Selection indicies for terminal sires to improve lean meat production from sheep in the United Kingdom. Anim. Prod., **45:** 87-96.

Pedersen, O.K., 1989. Current and future projects. In: Application of NMR techniques on the body composition of live animals, E. Kallweit, M.Henning and E. Groeneveld eds. Elsevier, New York. p. 159.

Price, M.A., 1995. Development of carcass grading and classification systems. In: S.D. Morgan Jones (Editor), Quality and Grading of Carcasses of Meat Animals, CRC Press, Boca Raton, pp 173-199.

Puntilla, M.L., 1986. Experiences using ultrasound scanner for evaluation of body composition in young Finnsheep rams. 37th Ann, Meet. EAAP, Budapest.

Puntilla, M.L. and Nylander, A., 1993. Possibilities to predict body composition from live animals in pure and crossbred Finnsheep. 43rd Ann. Meet. EAAP.

Purchas, R.W. and Beach, A.D., 1981. Between operator repeatability of fat depth measurements made on live sheep and lambs with an ultrasonic probe. N.Z. J. of Exp. Agr., **9:** 213-220.

Robelin, J. and Theriez M., 1981. Relationship between water and lipid content of empty body weight in growing cattle and sheep. Reprod. Nutr. Develop. **21:** 335-353.

Robelin, J., 1984. Prediction of body composition *in vivo* by dilution technique. D. Lister, (Editor), *In vivo* measurement of body composition in meat animals, Elsevier New York, pp. 106-112.

Ross, R., Leger, L., Guardo, R., Pike, B.G., de Guise, J., 1991. Adipose tissue volume measured by magnetic resonance imaging and computerized tomography in rats. J. Appl. Phys., **70:** 2164-2172.

Russel, A.J.F., 1995. Ultrasonography and body composition in sheep. In: P.J. Goddard (Editor), Veterinary Ultrasonography, CAB International, Wallingford, UK, pp. 315-324.

Sehested, E., 1984. Computerized tomography of sheep. D. Lister, ed. *In vivo* measurement of body composition in meat animals, Elsevier New York, pp. 69-74.

Shafto, A.M., 1996. Managing director, Sheep Information Centre, Canadian Sheep Federation, pers. comm.

Simm, G., 1983. The use of ultrasound to predict the carcass composition of live cattle - a review. Anim. Breeding Abstracts., **51:** 853-875.

Simm, G., Young, M.J. and Beatson, P.R., 1987. An economic selection index for lean meat production in New Zealand sheep. Anim. Prod., **45:** 307-316.

Simm, G., 1992. Selection for lean meat production in sheep. In: A.W. Speedy (Editor), Progress in Sheep and Goat Research. C.A.B. International, Wallingford, UK, pp. 193-215.

Simm, G., Dingwall, W.S. and Lewis, R.M., 1993. Genetic improvement of meat production. Proc. Third Int. Sheep Vet. Conf. Edinburgh, June 27-July 1.

Standal, N., 1984. Establishment of a CT facility for farm animals. In: D. Lister (Editor), *In vivo* measurement of body composition in meat animals, Elsevier New York, pp. 43-51.

Stouffer, J.R., 1988. Ultrasonics for live lamb and carcass evaluation. In: Methods to Improve the Lean Yield of Lamb. NC-III Technical Committee for Increased Efficiency of Sheep Production Symposium, Denver, CO. pp. 26-30.

Streitz, E., Baulain, U. and Kallweit, E., 1995. Investigation of body composition of growing lambs by means of magnetic resonance imaging. Zuchtungskunde, **67:** 392-403.

Swatland, H.J., 1995. On-Line Evaluation of Meat, Technomic, Lancaster, PA. pp. 347.

Taylor, C.S., 1965. A relation between mature body weight and time taken to mature in mammals. Anim. Prod., **7:** 203-220.

Thonney, M.L., Taylor, C.S., Murray, J.I. and McClelland, T.H., 1987. Breed and sex differences in equally mature sheep and goats. 2. Body components at slaughter. Anim. Prod., **45:** 261-276.

Timon, V.M. and Bichard, M., 1965. Quantitative estimates of lamb carcass composition. 3. Carcass measurements and a comparison of the predictive efficiency of sample joint composition, carcass specific gravity determinations and carcass measurements. Anim Prod., **7:** 189-201.

Vangen, O., 1989. X-Ray CT for body composition. In: Application of NMR techniques on the body composition of live animals, E. Kallweit, M.Henning and E. Groeneveld eds. Elsevier, New York. pp. 91-99.

Wells, P.N.T., 1984. Introduction to imaging technology. In: D. Lister (Editor), *In vivo* measurement of body composition in meat animals, Elsevier New York, pp. 25-35.

Wolf, B.T. and Smith, C., 1983. Selection for carcass quality. In: W. Haresign (Editor), Sheep Production. Butterworths, London, pp. 493-514.

Wang, J., Heymsfield, S.B. Aulet, M., Thorton, J.C., Pierson, R.N., 1989. Body fat from body density: underwater weighing vs dual photon aborptiometry. Am. J. Phys., **256:** E829-E834.

Ward, C.E., Trent, A, Hildebrand, J.L., 1995. Consumer perception of lamb compared with other meats. Sheep and Goat Res. J., **11(2):** 64-70.

Wood, J.D., Newman, P.B., Miles, C.A., and Fisher, A.V., 1991. Video image analysis: comparisons with other novel techniques for carcass assessment, Proc. Symp.Electronic Eval. Meat in Support of Value-Based Market, March 27-28, Purdue Univ., IN, pp. 145-169.

Table 1 1

Selected *in vivo* methods for prediction of body composition in sheep

Method	Dependent variable	Predictors	Precision	Authors
Subjective appraisal Ultrasound	lean meat yield (%)	estimated fat 12/13 ribs US[a] fat 12/13 ribs "C"	R^2=0 36, RSD=1 52 R^2=0 17, RSD=1 70	Edwards et al (1989)
Live weight Ultrasound	lean %	live weight (LW) LW + US "C" 12 rib	RSD=2 6 RSD=2 1	Cameron and Smith (1985)
Live weight Ultrasound Linear measures	trimmed boneless meat (kgs)	Live weight US LD[b] "B" LA[c]	R^2=0 76, RSD=0 29 R^2=0.79, RSD=0 27 R^2=0 89, RSD=0 20	Fortin and Shrestha (1986)
Live weight Ultrasound Ultrasound	lean meat yield (%)	LW LW+US LD "B" LW+"B"+US W[d] "A"	R^2 = 0 15, RSD=2 83 R^2=0 27, RSD=2 65 R^2=0 31, RSD=2 60	Puntila (1986)
Live weight Dilution (urea) Ultrasound	lean meat (kgs)	LW LW + urea space LW + US fat "C"	R^2=0 73, RSD=0 68 R^2=0 74, RSD=0 68 R^2=0 74, RSD=0 68	Jones et al (1982)
Linear measures Ultrasound Bioelectrical impedance Combination	lean meat yield (%)	LW + HG[e] + SH[f] LW+US "C"+US "B" LW+BL[g]+resistance + reactance LW+BL+resistance + reactance+US B"+US "C"	R^2=0 14, RSD=2 13 R^2=0 26, RSD=2 11 R^2=0 55, RSD=1 81 R^2=0.70, RSD=1 71	Berg et al (1996)
Liveweight X-ray CT	fat-free lean (kg)	LW LW + x-ray CT measures	R^2=0 83, RSD=0 80 R^2=0 92, RSD=0 61	Sehested (1984)
NMR	lean meat yield (%)	LW + NMR measures	R^2=0 78 to 0 91	Streitz et al (1995)

[a]US, ultrasound
[b]LD, longissimus depth
[c]LA, longissimus area
[d]W, longissimus width
[e]HG, heart girth
[f]SH, shoulder height

Table 1.2

Use of ultrasound in national programs for genetic improvement of lamb carcass composition

Country	Site used	Measures name	Program initiated	Year	Reference
Denmark	1st lumbar	C, LA[a]	Central Ram Test	1979	Jensen 1990
Australia	12th rib	C	Lambplan	1980[b]	Atkins et al. 1991
New Zealand	12th rib	C, A, B[d]	Animalplan[c]	1981	Davis and Fennessy 1996
Finland	1st lumbar	LA	Central Ram Test	1985	Puntilla & Nylander 1993
U.K.	3rd lumbar	C, B[d]	Sheepbreeder	1986	Simm 1992
Norway	1st lumbar	C, LA	Central Ram Test	1992	Puntilla & Nylander 1993
Canada	3rd lumbar	C, B	Ovissey	1997	Shafto 1996

[a]C=subcutaneous fat thickness over deepest part of longissimus , LA=longissimus area.

[b]1980, program initiated as New South Wales Meat Sheep Testing Service in 1980 which became Lambplan in 1989.

[c]Animalplan, known as Sheeplan until 1988

[d]A, maximum width of the longissimus; B, maximum depth of the longissimus.

Table 1.3

Manual/inexpensive methods of predicting carcass composition of sheep *ex vivo*

Method	Prediction	Predictors	Precision	Authors
Linear measures	lean meat yield (%)	fat depth "C"	R^2 = 0.43, RSD=3.00	Kempster et al. (1976)
		LW[a] "A"	RSD=3.85	
		LD[b] "B"	RSD=3.95	
		LA[c]	RSD=3.94	
		carcass weight (CW)	RSD=3.78	
		CW/carcass length	RSD=3.74	
Subjective appraisal	lean meat yield (%)	CW	RSD=3.63	Kempster et al. (1981)
		CW+external fatness (5)	RSD=2.97	
		CW+external fatness (15)	RSD=2.61	
Specific gravity	lean meat yield (%)	specific gravity	RSD=1.9	Kempster (1981)
Linear measures		kidney fat %	RSD=2.2	
Subjective appraisal		visual fat score	RSD=2.2	
Linear measures		LA, "A", or"B"	RSD=2.7	
Linear measures	lean meat yield (%)	CW	RSD=3.80 to 4.48	Kempster et al. (1986)
		CW + subjective fat (5)	RSD=3.08 to 3.44	
		CW + conformation (4)	RSD=3.63 to 4.31	
		CW + fat depth "C"	RSD=3.00 to 3.46	
		CW + LW "A"	RSD=3.52 to 4.01	
		CW + LD "B"	RSD=3.79 to 4.48	
		CW + kidney fat %	RSD=2.92 to 3.33	
		CW + % lean in shoulder	RSD=1.60 to 1.81	
Linear measures	carcass fat (%)	CW	RSD=3.31 to 3.77	Kirton et al. (1985)
		GR (manual by ruler)	RSD=2.91 to 3.11	
		CW + GR	RSD=2.86 to 3.11	
Subjective appraisal	lean meat yield (%)	MLC[d] fat score	RSD=2.91 to 3.31	Miles et al. (1991)
		MLC conformation score	RSD=3.31 to 4.52	

[a]LW, longissimus width
[b]LD, longissimus depth
[c]LA, longissimus area
[d]MLC, Meat and Livestock Commission of the UK

Table 1.4
High-technology methods of predicting carcass composition of sheep *ex vivo*

Method	Prediction	Predictors	Precision	Authors
Linear measures	lean meat	CW[a]	RSD=4.72	Harrington and Kempster
Linear measures	yield (%)	CW + subjective fat	RSD=2.75	(1989)
Optical probe		fat thickness (HP[b])	RSD=3.15	
Linear measures	carcass fat (%)	CW	RSD=3.53	Kirton et al. (1984)
Linear measures		CW+ GR (ruler)	RSD=2.16	
Optical probe		CW + GR (HP)	RSD=2.31	
Subjective appraisal	lean meat	visual fat score	R^2=0.16, RSD=44.5	Jones et al. (1992)
Optical probe	(g kg^{-1})	GR (HP) warm carcass	R^2=0.53, RSD=32.9	
Optical probe		GR (HP) cold carcass	R^2=0.58, RSD=31.0	
Linear measures	saleable	kidney fat (%)	R^2=0.13, RSD=2.54	Jones et al. (1993)
Linear measures	meat	GR (ruler), 12/13 rib	R^2=0.55, RSD=1.84	
Linear measures	yield (%)	CW +GR (ruler)	R^2=0.55, RSD=1.84	
Optical probe		GR, 12/13 rib (HP)	R^2=0.40, RSD=2.11	
Combination		GR (ruler)+ conformation score (5)	R^2=0.61, RSD=1.71	
Optical probe	carcass fat (%)	HP	RSD=3.07	Kirton et al. (1995)
Mechanical probe		Swedish FTC probe	RSD=3.25	
Mechanical probe		Aus-Meat probe	RSD=3.38[d]	
Mechanical probe		Ruakura GR probe	RSD=3.46	
Mechanical probe		GR (ruler)	RSD=2.97	
Ultrasound (speed)	lean meat	VUS[a], probe hind limb	RSD=3.34 to 3.83	Miles et al. (1991)
	yield (%)	VUS, probe shoulder	RSD=3.36 to 4.11	
Bioelectrical impedance	fat-free	CW	R^2=0.91, RSD=0.50	Jenkins et al. (1988)
	lean (kgs)	CW, CL[c]/resistance	R^2=0.94, RSD=0.42	
Total body electrical	lean meat	CW	R^2=0.00, RSD=1.66	Berg et al (1994)
conductivity (TOBEC)	yield (%)	CW + CL	R^2=0.35, RSD=1.51	
		CW+CL+TOBEC (best 2)	R^2=0.79, RSD=1.18	
Subjective appraisal	saleable meat	CW+sex+conformation	R^2=0.04, RSD=0.94	Horgan et al. (1995)
Video image analysis (VIA)	yield (%)	CW+sex+VIA (shape)	R^2=0.16 RSD=0.89	

[a]CW, carcass weight
[b]HP, Hennessy Lamb Probe
[c]LA, longissimus area
[d]High RSD due to inexperienced operator

CHAPTER 2

Lamb-buying preferences of Canadian abattoirs and producer marketing groups: implications for renewal of the Canadian lamb supply chain.

2.1 Introduction

Unless the 30 year trend of declining lamb consumption can be reversed, the North American sheep industry is threatened with extinction. Annual per capita lamb consumption on a retail-weight basis has plummeted to less than 1 kg in the U.S.A. (Economic Research Service 1994) and Canada (Statistics Canada 1995). The decline in per capita lamb consumption is likely the result of a breakdown in the lamb marketing channel, where the needs/wants of the majority of consumers are failing to be communicated to the primary producers. In a recent survey of American consumers (Ward et al. 1995), lamb was perceived as the least desirable of the red meats. American slaughter lamb prices have declined over 60% between 1978 and 1994, after adjustment for inflation (Purcell 1995). As the bulk of income for sheep producers is from sales of slaughter lambs, improvements have to be made in marketing channels in order to sustain the North American sheep industry.

Although the American sheep industry has been the subject of economic/marketing studies within the last decade (Purcell 1995, Brester and Musick 1995, Menkhaus et al. 1990), the smaller Canadian industry has been ignored since the Econolynx International study of 1992. The Econolynx study predicted the North American Free Trade Agreement (NAFTA) and subsequent imports of American lamb would precipitate the collapse by the year 2000 of the Canadian industry. As the American sheep industry has instead contracted, losing 35% of the breeding flock within the last 3 years (Su 1997) after the withdrawal of the wool incentive program, the Canadian sheep industry is no longer threatened by American imports. However, significant threats remain to the long-term viability of the Canadian industry.

The goal of this study was to investigate avenues for renewal of the Canadian lamb supply chain. Specifically, lamb buying preferences of Canadian abattoirs and marketing groups were surveyed to determine the transaction costs limiting upstream flow of information and downstream flow of lambs through Canadian lamb marketing channels.

2.2 Overview of the Canadian sheep industry

The majority of the Canadian flock (ewes + lambs on-farm July 1) is located in the provinces of Alberta (264,000), Ontario (227,000), Quebec (127,000), Saskatchewan (83,000) and British Columbia (83,000), with smaller flocks in the Maritime provinces and Manitoba (Statistics Canada 1996). A high proportion of the Canadian demand for lamb arises from ethnic groups of Mediterranean, Middle East or British origin. Accordingly, markets for lamb are located in the metropolitan centres (Toronto, Montreal, Vancouver) with large populations of the lamb-consuming ethnic groups. Canadian lambs have been sold by primary producers usually on a live weight basis either by public auction, to an order buyer, directly to an abattoir, to a lamb feedlot, or at the farm gate directly to the end consumer. Historically, farm gate (direct to consumer) sales have accounted for an estimated 47% of lambs marketed in Canada (Agriculture Canada 1977). The proportion sold at the farm gate increases during times of low slaughter lamb prices and is also influenced by proximity to urban centres. During the early 1990's in British Columbia, up to 70% of the lambs produced on Vancouver Island and the lower mainland were marketed at the farm gate (Carter 1997). Farm gate sales also play a significant role in the provinces of Manitoba, Ontario, Quebec and much of the Maritimes. However, the private nature of farm gate sales makes the collection of accurate data difficult. As an added complication, sheep producers may underestimate farm gate sales in an effort to avoid taxation.

Interprovincial transport of lambs plays a large role in Canadian lamb marketing. In 1996, of an estimated 240,000 western-Canadian market lambs, between 35 and 40% were slaughtered in western Canada, while the remainder were transported for slaughter in the provinces of Ontario and Quebec or exported live to slaughter plants in the western USA. In the Maritimes, 35 to 40% of market lambs were transported for slaughter into the province of Quebec. The long-distance transport of lambs has created an oligopoly of livestock dealers, with one livestock dealer controlling an estimated 50% of the Canadian lamb supply, excluding those lambs sold by the primary producer direct to consumers.

From 1975 to 1976, lambs were slaughtered at 74 federally inspected and 300 provincially inspected abattoirs. Of 139 plants which specified volume of slaughter, 78% processed less than 500 sheep and lambs over the two year period (Agriculture Canada 1977). In the 1990's, federal inspection of lambs has become highly concentrated in a total of 22 abattoirs: 12 in Quebec, 6 in Ontario, 2 in British Columbia and one plant in each of Alberta and Nova Scotia. The number of provincially inspected abattoirs processing lamb has increased to an estimated 400 plants in 1996 although the majority kill small numbers of lambs. When federal and provincial inspection is taken as a whole, the 10 largest abattoirs would likely process less than 50% of Canadian slaughter lambs. With the exception of the lambs slaughtered at the federally-inspected abattoir in Alberta, interprovincial export of lamb carcasses is limited.

Producer groups are a form of cooperative where members have a mutual incentive to comply with production quality standards (Hobbs 1995). Northumberlamb in Nova Scotia is an example of a producer group as lambs are accepted by the cooperative provided that they meet narrow carcass weight and finish specifications (Isenor 1997). Nine other groups centred in the province of Quebec marketed 35-40% of the 1995 provincial lamb crop (Demers 1996). The marketing groups in Quebec have established contracts with supermarkets, wholesalers/distributors and others for a regular weekly supply of lambs, the majority of which are sold as whole carcasses. Lamb quality is important to the Quebec marketing groups as they have targeted a high-quality "labelled" niche. Agneau Primeur du Quebec and Agneau Kamouraska are two of the labels for Quebec lambs. Members of the groups receive payment for their lambs on the basis of carcass weight and grade assigned by a marketing agent hired by each group.

2.3.1 Survey of Canadian abattoirs and lamb marketing groups

In July of 1997, a total of 23 abattoirs and lamb marketing groups (Table 2.1) were contacted by telephone and fax to determine their preferences toward a number of attributes of the supply channel for lambs in Canada. Abattoirs were required to assume ownership of lambs, while those functioning in a custom-killing capacity, including all abattoirs in Quebec, were not included in the survey. In Quebec and other parts of the country where marketing groups negotiate the sale of lamb carcasses, the marketing officers/managers of the cooperatives were surveyed. Marketing groups and abattoirs were required to have a volume of 10 lambs per week before they were included in the study.

The relative importance of a selected number of transaction costs (Table 2.2) in the lamb buying decisions of processors were determined by conjoint analysis (Hobbs 1996a, Hobbs 1996b). Although numerous factors affect the lamb-purchasing decisions of processors, the nature of the supplier (either long-term or occasional), the basis of payment for the lambs (either on liveweight, carcass weight, or carcass weight and grade), the handling of lambs (either direct uplift from farm to abattoir or handling more than once) and the price paid by the processor for the lambs (either market price, a 2% price premium, or a 2% price discount) were chosen for the conjoint analysis. The price paid by processors for lambs is not a transaction cost, but was included in the analysis to determine the value processors would place on a reduction in transaction costs (improved knowledge of carcass quality from payment on carcass weight and grade, lambs from long-term supplier and limited handling of lambs) compared to the price they were willing to pay for the lambs. Data for conjoint analysis were obtained from 16 lamb processors (6 in Ontario, 5 in Quebec, 3 in the Maritimes, 1 in each of Alberta and British Columbia). Design of scenarios was based on that described by Hobbs (1996b). Data were analysed in a fractional factorial design using the SPSS statistical program (SPSS 1990).

2.3.2 Results and Discussion

Five of the 23 processors initially contacted had either quit slaughtering lambs within the last 18 months or were killing lambs on a custom basis where they had previously bought outright. The majority of abattoirs (80%) which had recently ceased slaughtering lambs were located in British Columbia. The remaining lamb processors indicated that their lamb-buying practices and volume had generally remained stable over the last five years, with the only exceptions an abattoir which had recently quintupled its kill from 15 to 75 head per week and another which had halved its kill from 60 to 30 head per week.

The relative importance of various attributes of the supply channel in the full sample (n=16) and the part-worth evaluation of the attributes are shown in Table 2.3. Overall, the type of supplier was deemed least important, while the price paid by the processor for lambs was the most important attribute of the supply channel. As the price of lambs to processors has been at a historical high in 1996 and 1997 (Su 1997), these results are not surprising. Several processors commented that the high farm-gate price for lambs had recently eliminated some previously held markets for domestic lambs.

When the data in Table 2.3 were subdivided (Figure 2.1) into processors handling in excess of 100 lambs per week (n=6) and processors in the provinces of Quebec (n=5) and Ontario (n=6), some polarities became apparent in the relative importance of supply channel attributes. For large processors, supplier type became less important while price of the lambs assumed even greater relevance than for the survey respondents overall. The lamb-buying preferences of Quebec marketing groups and those of the abattoirs within Ontario were a contrast in extremes. As the success of a marketing group is largely tied to the integrity/loyalty of its members (Hobbs 1995), supplier type was much more important to the marketing groups than it was to abattoirs. Ontario abattoirs preferred to pay for lambs on the basis of live weight, while Quebec co-ops valued the basis of payment equally with price of the lamb to the co-op. Accordingly, grading of lambs would be met with extreme resistance in Ontario abattoirs, but welcomed by lamb marketing groups within Quebec. Handling of lambs (either once in a direct uplift from farm to slaughter, or more than once) was not important to the co-ops as transportation of lambs would be limited within the region of Quebec serviced by each co-op. In contrast, handling of lambs was as important for Ontario abattoirs as the price they paid for the lambs. Ontario abattoirs believed that "freshness"or "bloom" was proportional to the number of times the lamb was handled. Consequently, Ontario abattoirs would likely favour forward contracts with local sheep producers or marketing groups, provided that mutually acceptable descriptions of lamb quality could be devised.

Actual and predicted preference scores and ranks for the 11 scenarios in the survey are shown in Table 2.4. Although actual and predicted score and rank were in most cases similar, significant variation between actual and predicted scores occurred in 3 instances. Scenario 3 (occasional supplier, payment on carcass weight and grade, handled once, market price) was ranked as most preferred by survey respondents although the predicted rank for this scenario was fifth. Comments of "I would love to buy lambs this way" or "Too bad I can't buy lambs this way" were common among survey respondents. Perhaps the unexpected favour of scenario 3 is a reflection of the concentration of the Canadian lamb supply in the hands of an oligopoly of livestock dealers. Lamb processors might welcome the choice of buying lambs from an occasional supplier rather than negotiating with a small number of regular, "difficult" suppliers. Several abattoirs commented that "livestock dealers can never bring enough lambs." Livestock dealers would likely under-supply abattoirs in order to support the price of lambs, leading to widespread restrictions in availability of lambs if large proportions of the supply were held by a few livestock dealers. Scenario 5 which featured an occasional supplier was also more highly ranked than expected, which was likely due to the desire of some processors for additional choice in lamb suppliers.

Scenario 3 (long-term supplier, payment on live weight, handled once, valued at market price) while predicted to rank fourth, actually ranked seventh. As this scenario most closely approximates the manner in which many abattoirs currently buy lambs, downgrading of this scenario may be a symptom of dissatisfaction with the present lamb supply channel.

2.4 Conclusions

The lack of coordination/cooperation in the Canadian sheep industry was apparent in conducting this survey of Canadian lamb abattoirs. With the exception of Quebec and Nova Scotia, where establishment of producer marketing groups has removed some of the kinks in the supply chain, sheep producers need to start their own marketing groups and/or forge mutually beneficial forward contracts with abattoirs. However, before relationships can be developed with the abattoirs, it is necessary that sheep industry groups know where the lamb abattoirs are located, their estimated weekly volume and whether the abattoirs buy or custom-kill lambs. Sheep industry groups within the provinces of Ontario and British Columbia were without this basic information, which is unfortunate as Ontario sheep producers could benefit from the desire of abattoirs within the province to "maximize freshness."

The gap between concerns of lamb quality/seasonal availability and the need of abattoirs to control the cost of their lamb inputs can only be resolved through value-based marketing of lambs. Although marketing cattle under a value-based marketing system has been shown to increase marketing efficiency and reduced variability of producer profits compared to a carcass weight or live weight marketing (Feuz et al. 1993), the majority of Canadian lambs are currently marketed on a live weight (the least profitable) or carcass weight basis. Ironically, the group of Ontario abattoirs with a preference for buying lambs on a live weight basis were also those most concerned with lamb quality problems. However, many abattoirs bought lambs on a liveweight basis in order to ensure "freshness", which may necessitate warehousing live lambs until a market is found for their carcasses. Accordingly, use of technologies to increase accuracy of saleable meat yield/ carcass value prediction in live lambs are essential to improve the limited upstream flow of information to primary producers currently marketing lambs on a live weight basis.

The results of this study imply that abattoirs would welcome a greater variety of lamb suppliers to supplement their long-term relationships with livestock dealers. Livestock dealers have served as a necessary bridge between the widely separated centres of lamb supply and demand in Canada. However, an oligopoly of livestock dealers may have also increased the inefficiency of Canadian lamb abattoirs by restricting through-put.

Based on the results of this study, the survival of the Canadian Sheep Industry is dependant on:

1) Reduction of the proportion of lambs sold at the farm gate, allowing increased through-put of abattoirs and leading to increased economies of scale throughout the commercial supply chain. Education of sheep producers as to lamb preparation, marketing strategy to maximize profits is required.

2) Development of producer groups with innovative approaches to marketing lamb and a marketing officer to seek the best markets for lambs among all alternatives. The barriers against formation of marketing groups within the provinces of peak lamb demand (Ontario, Quebec and British Columbia) would be limited.

3) Improved carcass quality to meet consumer demand, achieved by carcass grading using Canadian Classification or other objective standards. For situations where live buying of lambs is obligatory, live carcass grading standards need to be developed using ultrasound or other objective technologies in order to allow upstream flow of information on carcass quality. Ultrasound measurements could be collected for $1.00 per head or less in most auction or order-buy situations.

4) Vertical cooperation in the form of forward contracting between abattoirs and producers/marketing groups which would stabilize the flow of lambs through the marketing channel and could at least partially address the problem of seasonality of supply. As the bulk of lambings in western Canada occur in March, shifting of a higher percentage of lambings to May would also help alleviate seasonality of lamb supply.

The main-stream marketing channel for Canadian lamb, similar to that in the USA, is inefficient due to oligopolies and oligopsonies in the slaughtering/processing industry. However, half of the Canadian supply of slaughter lambs bypasses the commercial channel and is sold at the farm gate, compounding existing inefficiencies in the marketing channel. The success of producer marketing groups within the province of Quebec demonstrates that the future is not necessarily bleak for the Canadian sheep industry. However, unless sheep producers, sheep industry groups and lamb abattoirs work together and make needed changes, the Canadian sheep industry in the future may be epitomized by isolated, non-commercial hobby flocks marketed direct to consumers at the farm gate.

2.5 References

Agriculture Canada 1977. Orientation of Canadian Agriculture: A task force report. Vol. 1 Part B, 560 pp.

Brester, G.W. and Musick, D.C. 1995. The effect of market concentration on lamb marketing margins. J. Agr. And Applied Econ. **27(1)**: 172-183.

Carter, G. 1997. Marketing Director, B.C. Sheep Federation, Personal Comm.

Demers, P. 1996. Portrait of the Quebec Sheep Industry, Proc., Int. Symp. on the Sheep Industry, October 11-12, Sherbrooke Quebec, p. 17-24.

Econolynx International Ltd. 1992. Economic study of the Canadian sheep and wool industry.

Economic Research Service. 1994. Red Meats Yearbook, U.S. Dept. Agric., Statistical Bulletin 885.

Feuz, D.M., Fausti, S.W., Wagner, J.J. 1993. Analysis of the efficiency of four marketing methods for slaughter cattle. Agribusiness **9(5)**: 453-463.

Hobbs, J.E. 1995. Evolving marketing channels for beef and lamb in the United Kingdom—a transaction cost approach. J. Int. Food Agribusiness Marketing **7(4)**: 15-39.

Hobbs, J.E. 1996a. Transaction costs and slaughter cattle procurement: processors' selection of supply channels. Agribusiness **12**: 509-523.

Hobbs, J.E. 1996b. A transaction cost analysis of quality, traceability and animal welfare issues in UK beef retailing. British Food J. **98**:16-26.

Isenor, M. 1997. Manager, Northumberlamb Lamb Marketing Cooperative Ltd., Truro, NS, Personal Comm.

Menkaus, D.J., Whipple, G.D., and Ward, C.E. 1990. Concentration in the lamb slaughtering industry: impact on lamb prices. Sheep and Goat Res. J. **6(1)**: 25-29.

Purcell, W.D. 1995. Economic issues and potentials in lamb marketing: keys to the future of the sheep industry. Sheep Goat Res. J. **11(3)**: 92-105.

SPSS 1990. SPSS Categories, SPSS Inc., Chicago, IL.

Statistics Canada 1995. Livestock Statistics. Publication No. 23-603E.

Statistics Canada 1996. Sheep census report, November.

Su, C. 1997. Market Economist, Alberta Agriculture, Food and Rural Development, Report for week ending February 21.

Ward, C.E., Trent, A., Hildebrand, J.L. 1995. Consumer perception of lamb compared with other meats. Sheep and Goat Res. J. **11(2)**: 64-70.

Table 2.1. Names and addresses of Canadian lamb abattoirs and marketing groups

Eastern Canada

Antigonish Abattoir, RR#4 Antigonish, NS, B2G 2L5, (902) 863-1545
Northumberlamb Lamb Marketing Cooperative Ltd. RR#2, Truro, NS, B2N 5B1, (902) 895-4262
Whitfield Farm, RR#1, Petitcodiac, NB, E0A 2H0, (506) 756-8263

Quebec

Le regroupement des bergers du Témiscamigue, 1030, route 101 nord, Saint Bruno de Guingnes, J0L 2Y0 (819) 728-2432.
Agneaumax, 343 rang 7 St. Nazaire, G0W 2V0 (418) 662-0543.
Cooperative ovine due KRT, 517 route 230, C.P. 304, St. Alexandre, G0L 2G0 (418) 495-5505.
Agneau Saglac, 6017 Ave Grande Pecharge, Delisle, G0W 1L0 (418) 347-3463.
Cooperative de commercialisations de ovins due Bas-Saint-Laurent, 170, range Massé Est., St. Gabriel de Rimorski, G0K 1N0 (418) 798-4141.

Ontario

Windcrest Meat Packers Inc., P.O. Box 82, Port Parry, L9L 1A2, (905) 985-7267
St. Helens Abattoir 1-3 Glen Scarlett Rd, Toronto, M6N 1P5, (416) 769-1788
J.J. Meat Distributing, 33 Wolverleigh Blvd., Toronto, M4C 1S5, (905) 859-1540
M. Gross Abattoir Ltd., 388 Clinton St., Toronto, M6G 2Z2 (416) 535-5924
Abingdon Meat Packers, 1607 Abingdon Rd, Caistor Centre, L0R 1E0 (905) 957-2223
Holly Park Meat Packers Inc. 8070 Old Church Rd., Bolton, L7E 5S1 (905) 880-1100
Millgrove Packers Ltd., RR#2 Waterdown, L0R 2H2 (905) 689-6184

Alberta

Canada West Foods Ltd., 4312-51 St., Innisfail, AB. T4G 1A3 (403) 227-3386

British Columbia

Grande Maison Meats, 5175 184 St., Surrey, V4P 1M5 (604) 576-8318.
Pitt Meadows Meat, 18315 Ford Rd., Pitt Meadows, V3Y 1Z1 (604) 465-4752.

Table 2.2. Survey form for collection of conjoint analysis data. Choices were rated on a scale of 1 to 12 where 1=least preferred and 12=most preferred. Respondents were encouraged to use the full scale from 1 to 12 when rating the different cases.

CASE	TYPE OF SUPPLIER	PAYMENT FOR LAMBS	HANDLING OF LAMBS	PRICE FOR LAMBS	SCORE
1.	Long-Term Regular	carcass weight+ grade	more than once	2% price premium	1 2 3 4 5 6 7 8 9 10 11 12
2.	Long-Term Regular	live weight	once/direct	market value	1 2 3 4 5 6 7 8 9 10 11 12
3.	Occasional supplier	carcass weight + grade	once/direct	market value	1 2 3 4 5 6 7 8 9 10 11 12
4.	Long-Term Regular	carcass weight	once/direct	2% price discount	1 2 3 4 5 6 7 8 9 10 11 12
5.	Occasional supplier	live weight	more than once	2% price discount	1 2 3 4 5 6 7 8 9 10 11 12
6.	Occasional supplier	carcass weight	once/direct	2% price premium	1 2 3 4 5 6 7 8 9 10 11 12
7.	Long-Term Regular	carcass weight	more than once	market value	1 2 3 4 5 6 7 8 9 10 11 12
8.	Long-Term Regular	carcass weight + grade	once/direct	2% price discount	1 2 3 4 5 6 7 8 9 10 11 12
9.	Long-Term Regular	live weight	once/direct	2% price premium	1 2 3 4 5 6 7 8 9 10 11 12
10.	Long-Term Regular	carcass weight + grade	once/direct	2% price discount	1 2 3 4 5 6 7 8 9 10 11 12
11.	Long-Term Regular	carcass weight	more than once	2% price discount	1 2 3 4 5 6 7 8 9 10 11 12

Table 2.3. Averaged conjoint results for the whole sample of Canadian lamb processors (n=16).

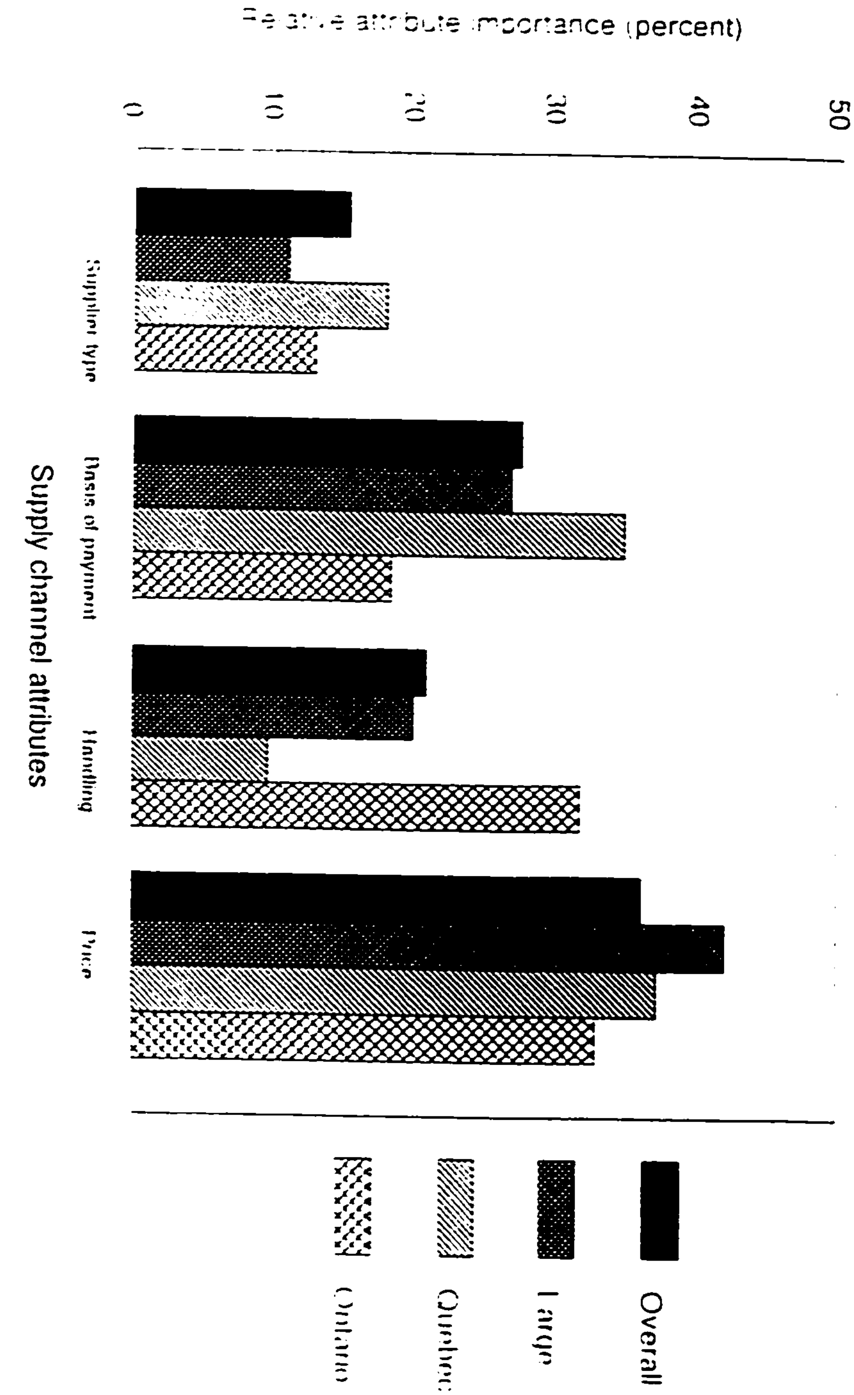
Attribute level	Part-worth evaluation	Relative importance of attribute (%)
Constant	7.2847	
Supplier		15.30
Long-term regular	0.7083	
Occasional	-0.7083	
Base of payment		27.65
Carcass weight and grade	0.7014	
Carcass weight	-0.0694	
Live weight	-0.6319	
Handling		20.86
Direct transport to plant	0.8333	
Lambs handled more than once	-0.8333	
Price paid by processor for lambs		36.18
2% price discount	0.5139	
Market value	0.0764	
2% price premium	-0.5903	
Correlation coefficient (Pearson's R)	1.000	
Kendall's Tau	1.000	

Table 2.4. Actual and predicted preference scores and ranks of various supply chain scenarios.

Scenario[a]	Actual average preference score	Actual rank	Predicted average preference score	Predicted rank
1	7.25	9	7.27	8
2	7.56	7	8.27	4
3	10.90	1	8.19	5
4	9.25	3	9.27	2
5	7.50	8	6.20	10
6	6.75	11	6.19	11
7	7.19	10	6.60	9
8	10.06	2	10.04	1
9	7.62	6	7.60	7
10	8.69	4	8.37	3
11	8.56	5	7.61	6

[a]See Table 2.2 for a description of scenarios

Figure 2.1 Relative importance of supply channel attributes for full sample of abattoirs (n=16), large (n=6, weekly volume > 100), Ontario-based abattoirs (n=6) and Quebec-based marketing groups (n=5).



CHAPTER 3

Use of ultrasound in prediction of carcass characteristics in lambs.

3.1 Introduction

In a recent Canadian study (Jeremiah et al. 1990), 92% of 2002 consumers surveyed identified excess fat as the primary reason for their refusal to purchase lamb rib chops. In the same study, low yield of meat, as reflected in small size of chops, was the second reason for consumer rejection of lamb (5%). In order to meet this consumer demand for leaner, more muscular lamb, the sheep industry must have the ability to identify live animals with superior carcasses for use in breeding programs. As the majority of Canadian lambs are marketed on a live weight basis, a method of live-grading or assessment is needed.

The use of ultrasound for measuring subcutaneous fat and muscling in live cattle has been well-documented (Stouffer et al. 1989; Faulkner et al. 1990). Compared to cattle and pigs, the use of ultrasound for body composition evaluation in sheep has been less successful. Purchas and Beach (1981) attributed anatomical differences in sheep such as the existence of wool, soft fat and mobile skin as possible reasons for reduced accuracy of ultrasonic measurements. Researchers (Leymaster et al. 1985; Fortin and Shrestha 1986; Edwards et al. 1989) concluded that for sheep, ultrasound lacked the required precision to be a useful predictor of carcass composition. Other studies (Jones et al. 1982; Hamby et al. 1986) concluded that ultrasound was only marginally useful for the prediction of carcass composition in sheep. However, encouraging results have

A version of this chapter was published. Stanford et al. 1995, Canadian Journal of Animal Science **75**:185-189.

been reported (Simm et al. 1990; Cameron and Bracken 1992) for improved body composition in sheep after three to four years of selection on indexes based on ultrasonic backfat, muscle depths and live weight.

In the majority of these studies, the authors measured subcutaneous fat and/or maximum depth of the longissimus muscle and/or cross-sectional area of the longissimus muscle between the 12th and 13th ribs, the most commonly used predictor of beef carcass lean content (Jones 1989a). Increased accuracy has been reported for ultrasonic measurements in rams at the first lumbar site (Jensen 1991) with correlations of 0.74 and 0.79 between ultrasonic and carcass measures of subcutaneous fat and longissimus area, respectively (Jensen 1977).

Federally inspected lamb carcasses in Canada have been evaluated under the Canadian Classification System since mid 1993. Under this system, warm carcasses are weighed, measured at the GR site and assigned subjective conformation scores ranging from 1 to 5 (1=severe lack of muscle and fat, 5=excellent conformation) for the regions of the leg, loin and shoulder.

The objective of this study was to evaluate real-time ultrasound measurements as useful predictors of carcass characteristics as measured by the Canadian Classification System for lamb.

3.2 Materials and Methods

One thousand one hundred and sixty two lambs were measured at the first lumbar vertebra using an Aloka SSD model 500 SEM (Aloka Co. Ltd., Tokyo, Japan) real-time ultrasound scanner equipped with a 150 mm 2 MHz probe at live weights ranging from 32.5 to 70.5 kg and ages ranging from 3 to 15 months. Lambs were rams, ewes and wethers and were also classified by type (meat or wool), with the meat type subdivided by frame size (small, medium or large) (Table 3.1). Wool type lambs included those of Rambouillet and Corriedale breeding; large meat type included lambs of Suffolk, Hampshire and Canadian Arcott breeding; medium meat type included Dorset, North Country Cheviot, Katahdin, Texel, Polypay and Rideau Arcott lambs; small meat type included lambs of Finn and Romanov breeding. All animals were cared for according to standards set by the Canadian Council of Animal Care.

All lambs were shaved over the first lumbar vertebra prior to measurement in order to remove any influence of wool on the ultrasound measurements. Ultrasonic measurements included subcutaneous fat, area of the longissimus (ribeye) muscle and maximum depth and width of the longissimus muscle. Subcutaneous fat, longissimus width and longissimus depth were measured using the electronic calliper directly from the screen of the scanner. Longissimus area was analyzed by tracing a print of the ultrasonogram on a digitizing tablet (NEC model PC-8875H, Tokyo, Japan). From videotape of the ultrasonograms, a randomly selected sub-sample of 200 longissimus areas were manually traced using a computer mouse, with the actual areas then determined by image analysis (Image 1/AT-C Imaging System, Empix Imaging Inc., Mississauga, Ontario, Canada).

Lambs were slaughtered within two days of ultrasonic measurement at Canada West Foods (Alberta) Corp, Innisfail. Warm carcass weight was recorded approximately 35 minutes after stunning. Soft tissue depth at the GR site (Kirton et al. 1979) and subjective muscling scores for the leg, loin and shoulder region of each carcass were determined by Agriculture Canada graders after chilling the carcasses for 3 to 6 h at 5° C. Carcass lean meat yield was calculated by using the equation (R^2 =0.51, residual standard deviation (RSD)=3.35%) of Jones et al. (1992).

$$\text{Lean \% yield} = 65.80 - 0.074\ \text{WT} - 0.432\ \text{GR}$$

where WT = warm carcass weight, GR = 6.38 + 0.88(total tissue depth (mm) at GR site). Saleable meat yield was determined directly by dissection into primal cuts for 57 of the lambs. These primal cuts included a square (bone in) shoulder, short cut leg, loin and rack. All cuts were then trimmed to have no more than 0.64 cm of subcutaneous fat. For all other lambs, saleable meat yield was determined using the equation (R^2 = 0.56, RSD = 1.3%) of Jones et al. (1993).

$$\text{Saleable yield \%} = 78.92 - 0.51\ GR + 1.25\ (ASM),$$

where ASM = average of the three subjective muscling scores, rounded to the nearest integer.

All statistical analyses were performed using the stepwise option of the REG and the STEPDISC procedures from the Statistical Analysis System Institute (1988). Stepwise regression with a quadratic model was used to assess the accuracy of ultrasonic measures in predicting carcass characteristics including lean meat yield, saleable meat yield and GR site measurement. Stepwise discriminant analysis was used to assess the accuracy of ultrasonic measures in predicting subjective conformation scores for the leg, loin and shoulder regions of the carcass.

3.3 Results and Discussion

The wide range of ages, breeds, sexes and live weights of lambs in this study were a representative sample of the yearly lamb slaughter in Alberta. Means, standard deviations, maximum and minimum values for age, weight and ultrasound measurements for the lambs used in this study are reported in Table 3.2. The two-fold range in weights and five-fold range in ages as well as the wide ranges in ultrasound measurements of fat and muscling, reveal the great diversity in the Alberta slaughter lamb population.

Prediction equations based on ultrasound values, age and live weights for meat-type lambs are shown in Table 3.3. Ultrasound values + age and weight had a significant, but weak relationship with lean meat yield (R^2=0.48, RSD=1.2). Saleable meat yield determined from carcass dissection was also accurately predicted by ultrasound (R^2=0.64, RSD=1.2), but carcass dissections were only performed on a small number of lambs (n=57). For saleable meat yield as determined by dissection, ultrasound fat was the only significant predictor ($P < 0.001$). Ultrasound measures of subcutaneous fat and longissimus depth were the most important predictors of GR, lean meat yield and saleable meat yield as determined by regression and accounted for more of the variation than did live weight or age^2. However, longissimus depth was negatively related to both lean and saleable meat yields, in apparent contradiction of the work of Jones et al. (1989b), later incorporated into the Canadian beef grading system, where longissimus area was positively correlated with carcass yield in beef. The difference between the work with cattle and the present study lies in the emphasis placed on carcass fat and the lack of impact of muscling on the equations for lean and saleable meat yields in lambs. Lean meat yield is determined solely by GR and carcass weight. As longissimus depth is positively correlated with carcass weight (r=0.49) and GR measurement (r=0.37) and both these factors negatively influence lean meat yield, the coefficient for longissimus depth in the regression on lean meat yield is therefore negative. Saleable meat yield is negatively influenced by GR, but positively influenced by subjective conformation score. However, fatter carcasses tend to have higher subjective conformation scores (r=0.30, r=0.35 and r=0.30 between GR and conformation scores of the leg, loin and shoulder, respectively).

Although conformation scores are on a 5 point scale, no lambs had overall scores of 1 and only 6 out of the 1162 lambs in the study had overall scores of 5. The impact of conformation score on saleable meat yield is therefore considerably reduced. With the exception of lambs with conformation scores of 5, saleable meat yield tended to decline with increasing conformation score. Mean saleable meat yields and standard errors were 79.1 $\pm$ 0.2, 77.4 $\pm$ 0.1, 77.1 $\pm$ 0.1 and 77.8 $\pm$ 1.1 for conformation scores of 2, 3, 4 and 5, respectively. It is only for lambs with muscle scores of 5 that the higher conformation score begins to outweigh the negative impact of a higher GR on saleable meat yield. If the Canadian Classification System for lamb included more emphasis on muscling, it is likely that ultrasound measurements of longissimus depth would have positive coefficients for predictions of meat yield.

Ultrasound measures of longissimus width and longissimus area, while significant predictors ($P < 0.15$) in a few cases, generally contributed little to the precision of the predictions of GR, lean meat yield and saleable meat yield. There was a correlation (r=0.84) between longissimus areas determined from the digitizing tablet and from image analysis (data not shown). Although determination of area by image analysis was only performed on a sub-sample of the data (n=200), accuracy of prediction of GR, lean meat yield and saleable meat yield were not improved compared to use of areas determined by the digitizing tablet. Work by (Jones et al. 1989b) has shown that longissimus area determined from carcass measurements can be a significant predictor of meat yield in cattle. The same would likely be true in sheep, provided that there was a method to accurately measure longissimus area using ultrasound. A possible cause for reduced accuracy of measurement using ultrasound is that several small muscles, the multifidus dorsi and the longissimus costarum, lie in close proximity to the longissimus muscle. In lambs lacking a layer of intermuscular fat, these smaller muscles may appear to be part of the longissimus muscle in an ultrasound image. Further refinements in ultrasound technology may be necessary to solve this problem.

Relationships between mean subjective conformation score and ultrasound measurement of longissimus depth are shown in Figure 3.1. Lambs with a range of longissimus depth measurements between 17 and 32 mm were all given a conformation score of 3. Similar trends were found for other ultrasound measurements (data not shown) indicating that none of the ultrasound measurements were particularly useful in the prediction of conformation score. Perhaps the subjective nature of the conformation score interferes with their prediction. As the Canadian classification system for lamb has just been implemented, some additional refinements to the conformation score system, such as an objective measuring system, may still be needed.

When lambs were grouped by type and frame size in stepwise regression analyses, differences between wool and meat-type lambs became apparent. For wool-type lambs (Table 3.4), age^2 explained more of the variation for lean and saleable meat yields than did any of the ultrasound measurements. In contrast, for meat-type lambs (Table 3.3), ultrasound measures of subcutaneous fat and longissimus depth were the most significant predictors of lean and saleable meat yields. As carcass dissections were only performed on large and medium meat-type lambs, it is not known if this difference would have also carried over to dissection results. All of the wool-type lambs over 7 months of age in this study were imported from the USA to make up the shortfall in Alberta lamb slaughter in the early spring. As age is the most significant predictor of lean and saleable meat yields in wool-type lambs, these results may reveal the disparity between the younger, Alberta bred wool-type lambs and the older, leaner, more lightly muscled American lambs.

In stepwise discriminant analyses by type and frame size, ultrasound appears to be a more accurate predictor of subjective conformation scores for small-frame lambs

(R^2=0.57, 0.78, 0.66) than for large frame lambs (R^2=0.21, 0.20, 0.19), medium frame lambs (R^2=0.20, 0.33, 0.27) or wool-type lambs (R^2=0.27, 0.24, 0.38) for the leg, loin and shoulder, respectively. Gilbert et al. (1993) found that the presence of subcutaneous fat impeded the accurate prediction of carcass composition by use of body dimension measurements in cattle. As small-frame lambs were mainly of Romanov and Finn breeding, the reduced amounts of subcutaneous fat in these breeds may be responsible for the increased accuracy of ultrasound in predicting subjective conformation scores.

Previous work in ultrasound measurement of carcass composition has used low numbers of lambs ($n < 40$) (Jones et al. 1982; Leymaster et al. 1985; Hamby et al. 1986; Edwards et al. 1989) and/or did not have access to current real-time technology (Jones et al. 1982; Leymaster et al. 1985; Fortin and Shrestha 1986). These limitations may explain the conclusions by those researchers that ultrasound had either limited or no value in the prediction of carcass composition in lambs. The most recent of these studies (Edwards et al. 1989) reported ultrasound measurements of subcutaneous fat and longissimus area were not significant ($P > 0.15$) predictors of carcass yield when the carcass was not trimmed of external fat. They found that R^2 values for prediction of carcass yield increased to 0.24 when the carcass was closely trimmed to a maximum of 0.64 cm of external fat. These results are in contrast to our data (Table 3.3) where due to a larger numbers of lambs of differing genetic make up, an R^2 of 0.64 was obtained between ultrasound measurement of subcutaneous fat and saleable meat yield from dissection when primal cuts were also trimmed to 0.64 cm of external fat.

From these results, it appears that real time ultrasound measurements of subcutaneous fat depth and longissimus muscle depth in conjunction with live weight and age can explain approximately half of the variation associated with GR site measurement, lean meat yield and saleable meat yield in lambs. However, ultrasound is less successful in the prediction of subjective conformation scores, with the exception of small-frame lambs (Romanov and Finn breeding). As ultrasound measurements are relatively rapid and inexpensive to obtain, this study demonstrates that ultrasound can be a valuable tool in identifying lambs with desirable carcass characteristics as determined by the Canadian Classification System for lamb. The next challenge will be to implement a program of ultrasound selection of breeding stock as is currently in place in Australia, New Zealand and Great Britain, in order to meet consumer demand for lean, well-muscled lambs.

3.4 References

Cameron, N.D. and Bracken, J. 1992. Selection for carcass lean content in a terminal sire breed of sheep. Anim. Prod. **54**: 379-388.

Edwards, J.W., Cannell, R.C. Garret, R.P., Savell, J.W., Cross, H.R. and Longnecker, M.T. 1989. Using ultrasound, linear measurements and live fat thickness estimates to determine the carcass composition of market lambs. J. Anim. Sci. **67(12)**: 3322-3330.

Faulkner, D.B., Parrett, D.F., McKeith, F.K., Berger, L.L. 1990. Prediction of fat cover and carcass composition from live carcass measurements. J. Anim. Sci. **68**: 604-610.

Fortin, A. and Shrestha, J.N.B. 1986. In vivo estimation of carcass meat by ultrasound in ram lambs slaughtered at an average live weight of 37 kg. Anim. Prod. **43**: 469-475.

Gilbert, R.P., Bailey D.R.C. and Shannon N.H. 1993. Body dimensions and carcass measurements of cattle selected for postweaning gain fed two different diets. J. Anim. Sci. 71:1688-1698.

Hamby, P.L., Stouffer, J.R. and Smith, S.B. 1986. Muscle metabolism and real- time ultrasound measurement of muscle and subcutaneous adipose tissue growth in lambs fed diets containing a beta-agonist. J. Anim. Sci. **63**: 1410-1417.

Jensen, N.E. 1977. Preliminary results from Danscan ultrasonic measurements of fat thickness and loin area of lamb. Proc of European Assoc. for Anim. Prod., 28th Annual Mtg, pages 74-78.

Jensen, N.E. 1991. Personal communication.

Jeremiah. L.E., Gibson, L.L., and Tong, A.K.W. 1990. Retail acceptability of lamb as influenced by sex and slaughter weight. Can. J. Anim. Sci **70(4)**: 1179- 1180 (Abstr).

Jones, S.D.M., Walton, J.S., Wilton, J.W. and Szkotnicki, J.E. 1982. The use of urea dilution and ultrasonic backfat thickness to predict the carcass composition of live lambs and cattle. Can. J. Anim. Sci. **62**: 371-379.

Jones, S.D.M. 1989. Quantitative methods of carcass evaluation. Proc. Reciprocal Meat Conference **42**: 57-63.

Jones, S.D.M., Tong, A.K.W. and Robertson, W.M. 1989. The prediction of beef carcass lean content by an electronic probe, a visual scoring system and carcass measurements. Can. J. Anim. Sci. **69**: 641-648.

Jones, S.D.M., Jeremiah, L.E., Tong, A.K.W., Robertson, W.M. and Gibson, L.L. 1992. Estimation of lamb carcass composition using an electronic probe, a visual scoring system and carcass measurements. Can. J. Anim. Sci. **72**: 237-244.

Jones, S.D.M., Robertson, W.M. and Price, M. A. 1993. The assessment of saleable meat yield in lamb carcasses. Int. Congress Meat Sci. & Technology, Calgary, Session 4. page 190 (abstr).

Kirton, A.H. and Johnson, D.L. 1979. Interrelationships between GR and other lamb carcass fatness measurements. Proc. New Zealand Soc. Anim. Prod. **39**: 194-201.

Leymaster, K.A., Mersmann, H.J. and Jenkins, T.G. 1985. Prediction of the chemical composition of sheep by use of ultrasound. J. Anim. Sci. **61(1)**: 165-172.

Purchas, R.W. and Beach. A.D. 1981. Between operator repeatability of fat depth measurements made on live sheep and lambs with an ultrasonic probe. New Zealand J. Exp. Agr. **9**: 213.

Statistical Analysis System Institute Inc., 1988. SAS/STAT User's Guide, Release 6.03 Edition. Cary, N.C.:SAS Institute Inc., 1988, 1028 pp.

Simm, G., Dingwall, W.S., Murphy, S.V., FitzSimmons, J. & Brown, W.R. 1990.

Selection for improved carcass composition in Suffolk sheep:interim results. Anim Prod. **49**: 547 (Abstr).

Stouffer, J.R., Perry, T.C. and Fox, D.G. 1989. New Techniques for real time ultrasonic evaluation of beef cattle. J. Anim. Sci. **67**: 121 (Abstr).

Table 3.1. Numbers of lambs by gender, type and frame size

	GENDER			
FRAME SIZE/TYPE	Ram	Ewe	Wether	Totals
Large	135	190	178	508
Medium	132	125	131	388
Small	30	56	40	126
Wool Breed	8	99	37	144
TOTALS	305	470	386	1166

Table 3.2. Age, weights and ultrasound values of lambs (N=1162)

Variable	Mean	SD[z]	Minimum	Maximum
Age (months)	6.85	2.30	3.00	15.00
Liveweight (kg)	47.88	4.31	32.50	70.20
Warm carcass weight (kg)	23.21	2.52	16.00	36.20
Subcutaneous fat (mm)[y]	4.60	1.53	1.00	11.00
GR (mm)	12.41	3.98	2.00	25.00
Longissimus depth (mm)[y]	23.82	2.55	17.00	34.00
Longissimus width (mm)[y]	37.97	5.71	22.00	61.00
Longissimus area (cm^2)[y]	16.98	3.70	4.00	34.40
Lean meat yield (%)	56.97	1.61	51.45	60.82
Saleable meat yield (predicted %)	77.41	2.34	70.34	81.18
Saleable meat yield (actual %)[x]	77.27	2.00	73.11	80.31

[z] standard deviation

[y] ultrasound measurement

[x] n=57

Table 3.3. Equations for calculating carcass characteristics for meat-type lambs (n=1022) from ultrasound, age and liveweight measurements

	Predicted variables (Partial R^2 in brackets)			
Regression coefficients	GR^z	Lean meat yield %^{y}	Saleable meat yield %^{x}	Saleable meat yield %^{w}
Intercept	-21.51	64.92	85.14	80.97
Ultrasound subcut. fat	1.44	-0.49	-0.59	-0.82
	(0.41)	(0.32)	(0.22)	(0.64)
Ultrasound longiss. depth	0.29	-0.18	-0.22	NS^w
	(0.04)	(0.09)	(0.05)	
Ultrasound longiss. width	-0.14	0.03	0.04	NS^w
	(0.02)	(0.02)	(0.005)	
Ultrasound longiss. area	0.10	NS^w	NS^w	NS^w
	(0.001)			
Age x Age	NS^w	0.01	0.02	NS^w
		(0.03)	(0.09)	
Liveweight	0.85	-0.07	0.85	NS^w
	(0.02)	(0.02)	(0.005)	
R^2	0.49	0.48	0.37	0.64
RSD^v	2.8	1.2	1.9	1.2

^{z} GR expressed in mm.

^{y} determined from equation (Jones et al. 1992).

^{x} determined from equation (Jones et al. 1993).

^{w} determined from carcass dissection (n=57).

^{w} not significant (P > 0.15).

^{v} residual standard deviation.

Table 3.4. Equations for calculating carcass characteristics from ultrasound, age and liveweight measurements for wool-type lambs

Regression Coefficients	Predicted variable (Partial R^2 in brackets)	
	Lean Meat yield %[z]	Saleable meat yield %[y]
Intercept	59.75	79.11
Ultrasound subcutaneous fat	-0.31	-0.46
	(0.10)	(0.07)
Ultrasound longissimus depth	-0.16	-0.19
	(0.02)	(0.02)
Ultrasound longissimus width	0.06	0.10
	(0.04)	(0.01)
Age x Age	0.03	0.05
	(0.42)	(0.47)
Liveweight x Liveweight	-0.001	-0.001
	(0.04)	(0.02)
R^2	0.62	0.59
RSD[x]	1.5	1.7

[z] determined by equation (Jones et al. 1992)

[y] determined by equation (Jones et al. 1993)

[x] residual standard deviation %

Figure 3.1. Relationship between mean subjective conformation score and depth of the longissimus muscle for lambs (n=1162).

Longissimus depth (mm)

```
34 +                    A
33 +
32 +          A                   A
31 +          B         A
30 +          H         C
29 +          Q         F
28 +          Z         M
27 +  B       Z         P         A
26 +  E       Z         P
25 +  K       Z         U
24 +  I       Z         Q
23 +  J       Z         K
22 +  V       Z         D
21 +  P       Z         D
20 +  U       Y         A
19 +  Q       Q
18 +  E       H
17 +  D       B

   --+---------+---------+---------+-
     2         3         4         5
```

Subjective conformation score

Legend: A = 1 obs, B = 2 obs, etc.

CHAPTER 4

Ultrasound evaluation of Suffolk-cross ram and ewe lambs from birth to 180 d of age

4.1 Introduction

Ultrasound has been used to estimate lamb carcass composition in genetic evaluation programs in many countries including New Zealand (Dodd et al. 1986), Britain (MLC 1987), Denmark (Jensen 1990), Australia (Atkins et al. 1991), Norway (Olesen and Husabø 1994) and Canada (Gallivan and Hosford 1997). The measurements commonly used in these lamb carcass-improvement programs were first described by Pálsson (1939): 'A', the maximum width of the longissimus muscle; 'B', the maximum depth of the longissimus perpendicular to 'A'; 'C', the depth of subcutaneous fat over 'B' and LEA, the cross-sectional area of the longissimus muscle (Figure 4.1). Ultrasound measurements of 'B' and 'C' have been shown to be valuable predictors of lamb carcass saleable meat yield (Stanford et al. 1995; Hopkins et al. 1996), while 3 years of selection based on reduced ultrasound measurements of 'C' at a given live weight increased carcass lean and reduced carcass fat in lambs by approximately 14 g kg^{-1} (Cameron and Bracken 1992).

The guidelines for age and weight of lambs at ultrasound measurement vary among genetic evaluation programs and are determined by the traditional lamb marketing practices of the region or nation. Some programs such as the Australian LAMBPLAN allow ultrasound measurement over a wide range in ages (5 to 18 months; Gilmour et al.

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1994), where others such as the British (MLC 1987) and Canadian (Gallivan and Hosford 1997)

Suffolk sire-referencing schemes target measurement for lambs of 147 and 100 d of age, respectively. Due to the expense of the equipment and labour involved, collection of ultrasound data occurs infrequently (usually once per flock per year). Accordingly, lambs may range widely in age and weight when ultrasound measurements are recorded, due in part to the variation in lambing dates within a flock.

Based on over 30 yr of experimental data, ultrasound has been recognized as the technology of choice for beef carcass-improvement programs (Whittaker et al. 1992). Beef researchers (Simm et al. 1983; Turner et al. 1990; Hamlin et al. 1995) have recognized the need for ultrasound measurements to be adjusted to a constant age or weight basis so that the genetic differences in carcass composition can be determined. The development of these adjustment equations has required collection of ultrasound measurements of cattle over a range of ages and weights, with separate equations for different sexes and biological types (Wilson 1992). In contrast, previous lamb studies using serial ultrasound measurements have focussed on the prediction of saleable meat yield (Hopkins et al. 1996), carcass chemical composition (Bennett et al. 1988) or lamb market-readiness (Hopkins et al. 1993). The goal of the following study was to identify the effects of age, weight and sex on ultrasound measures of 'A', 'B', 'C' and LEA from birth to 180 d of age in Suffolk-cross lambs.

4.2 Materials and Methods

All animals were cared for according to standards set by the Canadian Council on Animal Care. Sponges containing 60 mg medroxyprogesterone acetate (Veramix®, Upjohn, Tuco Products Company, Orangeville, ON) were inserted intravaginally in mature (age 2 to 5 yr) Suffolk ewes (n = 37) and removed after 14 d. At sponge removal, Romanov rams were introduced to the ewes for a period of 34 d. The lambs (n = 78) resulting from these matings were born over a 36 d interval, with 85% of lambs born within 14 d. Only lambs born and reared as twins (n = 74) were included in the study. Lambs were housed in group pens with their dams and allowed ad libitum access to a 19% CP creepfeed (Table 4.1).

When the oldest lambs reached 14 d of age, they were shaved to remove all wool over the longissimus muscle at the first lumbar vertebra. The weight of the lamb was noted and an ultrasonogram at the first lumbar vertebra was recorded on video tape using a Tokyo-Keiki model CS-3000 ultrasound scanner equipped with a 5 cm 3.5 MHz probe (Tokyo-Keiki Co. Ltd., Tokyo, Japan). An electronic calliper was used to determine 'A', 'B' and 'C' directly from the screen of the scanner. Longissimus area was measured by image analysis (Image 1/AT-C imaging system, Empix Imaging Inc., Mississauga ON) of the video tape.

After weaning at a mean age of 65 d, lambs were housed in same-sex pens and allowed ad-libitum access to water and a 14.5% CP, pelleted lamb-grower diet typical for western Canada (Table 4.1). Lambs were randomly assigned within sex to 3 groups which were slaughtered upon reaching live weights of 40 to 43 kg, 44 to 47 kg and 48 to 52 kg, respectively. Lamb weight and ultrasound measurements (Table 4.2) were recorded at bi-weekly intervals until slaughter. Upon reaching their target weight, the final ultrasound data were collected and lambs were slaughtered within 1 d at a commercial abattoir. After the carcasses had chilled at 5°C for a minimum of 2 h, carcass length was measured from the point of the scapula to the distal end of the tarsals as described by Stanford et al. (1997).

All statistical analyses were performed using the general linear model (GLM) and the stepwise option of the REG procedure of the SAS Institute (1994). A preliminary analysis of covariance used the following model:

$$\text{ultrasound variable}_{ij} = \mu + \text{sex}_i + \beta\text{weight}_{ij} + \text{interaction of sex}_i \text{ with } \beta\text{weight}_{ij} + \epsilon_{ij}$$

As a significant interaction of sex by the covariate weight was present for all ultrasound variables, a separate slopes analysis was done using the model:

$$\text{ultrasound variable}_{ij} = \mu + \text{sex}_i + \beta_i \text{ weight}_{ij} + \epsilon_{ij}$$

For each date of ultrasound measurement, analysis of variance was used to determine the effect of sex on longissimus dimensions and 'C', with and without weight of the lamb as a covariate. Means were compared using a least-squares-mean linear hypothesis test. Regression with a quadratic model was used to assess the accuracy (by sex) of weight, weight^2, age and age^2 in predicting ultrasound measurements. Preliminary repeated measures analyses were done to determine the effects of age or weight on the ultrasound measurements of individual lambs. Results of these analyses indicated no difference in the effects of age or weight on individual animals as compared to grouping animals within sexes.

4.3 Results and Discussion

4.3.1 Animals

Although 74 lambs were used in this study, not all lambs were subject to ultrasound measurements at all the ages identified in the experimental design. For measurements at 15, 30 and 45 d of age, a minimum of 52 and maximum of 60 lambs were measured, although all 74 lambs were measured at one or more of these ages. After ultrasound measurement at 135 d of age, the first lambs reached their target weight and were slaughtered, leaving 55, 35 and 26 lambs available for study at ages of 150, 165 and 180 d, respectively.

The range of slaughter weights chosen for the study were representative of lambs in western Canada (Stanford et al. 1995). The range of age at slaughter (134 to 185 d, Table 4.2), would also be typical for lambs fed high-concentrate diets. As all lambs were born and reared as twins by mature ewes and were of a narrow range of age, they formed a single management group as defined by genetic improvement programs (Shrestha et al. 1985; Gilmour et al. 1994). Single-born lambs (n = 4) were excluded from the study due to the influence of birth rank on live weight and ultrasound measurement of 'C' (Atkins et al. 1991; Gallivan and Hosford 1997).

4.3.2 Effect of sex on longissimus dimensions

Due to the importance of the longissimus muscle in the development of efficient locomotion, it has a high growth impetus immediately after birth (q = 0.7) and a low impetus after the lamb reaches 20% of its mature weight (q = 1.2; Butterfield 1988). It has generally been assumed that LEA, 'A' and 'B' are proportional to live weight (Nicoll et al. 1992; Hamlin et al. 1995), providing that animals are of similar breed and age. Limited attention has been paid to the effect of sex on the cross-sectional dimensions of the longissimus, although the weight of the muscle in lambs of different ages and sexes has been well established (Fourie et al. 1970; Jury et al. 1977; Butterfield 1988).

In the present study, ewe lambs had significantly ($P < 0.05$) lower live weights than ram lambs after 90 d of age (Figure 4.2) while LEA, 'A' and 'B' did not differ between ram and ewe lambs until 180 d of age (Figures 4.3-4.5). Adjustment of longissimus dimensions by weight of the lamb resulted in significantly larger measurements of LEA and 'B' for ewe as compared to ram lambs from 90 to 180 d of age (Figures 4.3, 4.5). Although longissimus width, 'A' (Figure 4.4) was less affected by adjustment for liveweight than was LEA or 'B', 'A' and LEA have been found to be less accurately measured by ultrasound than 'B' (Hopkins et al. 1993; Stanford et al. 1995). Consequently, 'B' has been advocated for inclusion in genetic indices for lean meat production in sheep (Gilmour et al. 1994).

In populations of sheep selected for improved carcass composition, ewe lambs have been found to have a longissimus depth equal to that of ram lambs when compared at equivalent (100 d) age but unequal live weights (Gallivan and Hosford 1997). As measurements were made with crossbred Suffolk in the present study and with purebred Suffolk in the study of Gallivan and Hosford (1997), the results are not directly comparable, although the measurements in both studies were made at the first lumbar vertebra. It becomes apparent, though, that cross-sectional longissimus dimensions of ewes may be larger than would be predicted by their live weight when compared to those of ram lambs of similar breeding and age.

The ratio of ram and ewe live weight at maturity has been estimated at 1.3 for animals of similar genotype and nutritional regime (Hammond 1932). The proportionally larger cross-sectional longissimus dimensions of ewe as compared to ram lambs between 90 and 180 d of age may be a result of the greater physiological maturity of the ewe lambs over this age range. Providing that nutrition is adequate, and considering only those lambs born without the aid of light control or exogenous hormones, most lambs enter puberty between 120 and 180 d of age (Dýmundsson 1987). Perhaps ewe lambs have a proportionally thicker longissimus muscle than rams at puberty in order to prepare the ewe lambs for the ensuing rigours of pregnancy.

Ultrasound measurement of 'B' has been shown to be negatively correlated with carcass length (Hopkins et al. 1993). In the present study, when carcass length was adjusted for age, rams had slightly longer carcasses than ewes (104.6 compared to 103.4 cm, data not shown) although the difference was not significant. In some of our previous work (Stanford et al. 1997) comparing 1397 carcasses of multiple breeds from lambs of 110 to 345 d of age, ram lambs had significantly longer carcasses than ewe lambs (105.1 and 103.3 cm, respectively). Jury et al. (1977) found that after 77 d of age, ram lambs had a higher weight of muscles around the spinal column as a percentage of carcass muscle weight than did ewe lambs. Accordingly, when compared at equal body weights at an age of 90 to 180 d, ram lambs would likely have a higher weight of the longissimus muscle than would ewe lambs. The results of the present study demonstrated that the longissimus muscle may be relatively shallower in cross-section in rams of 90 to 180 d of age as compared to ewes of the same age and breeding. It is probable that greater length of the longissimus muscle in rams may account for the relatively higher weight of the muscle in rams as compared to ewes.

4.3.3 Effect of sex on fat measurements

Backfat measurement 'C' did not differ between the sexes until 180 d of age (Figure 6) when it became higher ($P < 0.05$) in rams than in ewes. As expected, rams grew more rapidly (330 ± 8 g d^{-1}) than the ewes (284 ± 7 g d^{-1}) during the course of the study. The majority of rams slaughtered at 180 d of age were > 48 kg live weight, while ewe lambs were evenly split between the three weight categories. The 'C' of the ram lambs at 180 d was likely a reflection of their higher live weight compared to that of the ewe lambs. When 'C' was adjusted for differences in live weight (Figure 6), ewe lambs had higher measurements than rams from 120 to 165 d of age. Other than the anomalous fat measurement at age 180 d, these results were expected. Lambs are normally slaughtered at 50 to 60% of their mature weight (McClelland et al. 1976) and ewe lambs have been found to deposit a greater proportion of subcutaneous fat than rams after reaching 60% of mature weight (Butterfield 1988). Accordingly, sex differences in weight-adjusted fat measurements became apparent in the present study when the first lambs reached their targeted slaughter weights.

4.3.4 Effects of age on ultrasound measurements

Within 14 d of birth, most lambs had only traces of subcutaneous fat. Backfat depth 'C' reached measurable levels within 28 d of birth, but did not attain 3 mm for either sex until lambs were 90 d of age (Figure 4.6). The dimensions of the longissimus in neo-natal lambs (Figures 4.3-4.5) although small within 14 d of birth, were measurable with ultrasound. As measurement error increases proportionally with decreasing size of the ultrasound image (Olesen and Husabø 1994), genetic improvement programs must balance the need to finalize selection decisions before lambs reach market weight with the need for sufficient size/variability in the parameters measured to allow effective genetic selection. The genetic improvement program for sheep in New Zealand has recommended collecting ultrasound measurements when lambs weigh at least 35 kg (Dodd et al. 1986). Similarly, the Australian program, LAMBPLAN, has set minimum weights at ultrasound measurement of 30 and 32 kg for ewes and rams, respectively (Gilmour et al. 1994). One hundred-five to 133 d was determined by Bennett et al. (1988) to be the age at which selection differentials for weight of carcass fat and lean become established in lambs. Lambs in the present study did not reach the live weights specified under LAMBPLAN (Gilmour et al. 1994) until between 105 and 120 d of age, although 'C' was equal to that of the Australian lambs by 90 to 105 d of age. For rapidly-growing lambs fed high-concentrate diets, collection of ultrasound data at approximately 100 d after birth would appear to allow sufficient size/variability of the ultrasound parameters and time to allow processing of the ultrasound data prior to slaughter.

In stepwise regressions by sex with age, age^2, weight and weight^2 in the model, age was the only significant ($P < 0.15$) predictor of LEA, 'A', 'B', or 'C' (Table 3). In agreement with the work of Hopkins et al. (1996), live weight and live weight^2 were poor predictors of longissimus dimensions and 'C' of lambs. In contrast, Hamlin et al. (1995) found that both age and weight had significant effects on ultrasound measurements of fat thickness and longissimus area, although the steers of Hamlin et al. (1995) were of a wider range in age (90 d) than the lambs in the present study.

Gilmour et al. (1994) determined that adjustment of ultrasound measurements of 'A', 'B' and 'C' by live weight, removed all effects of age, birth type, rearing type and dam type, although the lambs in that study were of a wide (90 d) range in age and from 79 different farms/management groups. Perhaps, as in the present study, age is the most important factor for adjustment of ultrasound data in lambs from a single management group while live weight becomes the most important factor affecting ultrasound measurements in lambs of wide-ranging ages and management groups.

4.4 Conclusions

Age of lamb greatly influenced ultrasound measurement, accounting for 63, 75, 76 and 81% of the variation associated with subcutaneous fat depth 'C', longissimus width 'A', longissimus depth 'B' and longissimus area in Suffolk-cross ram lambs. Quadratic effects of age on longissimus dimensions and backfat depth were not significant for lambs between birth and 180 d of age. When ultrasound measurements were adjusted by live weight, ewe lambs of 90 to 180 d of age had significantly larger measurements of

'B' and LEA than ram lambs of similar ages. Consequently, adjustment of ultrasound data by liveweight may result in larger longissimus dimensions for ewe as compared to ram lambs when measurements are collected from Suffolk-cross lambs between 90 and 180 d of age.

4.5 References

Atkins, K. D., J. I. Murray, A. R. Gilmour, and A. L. Luff. 1991. Genetic variation in liveweight and ultrasonic fat depth in Australian Poll Dorset sheep. Aust. J. Agric. Res. **42**:629-640.

Bennett, G. L., H. H. Meyer, and A. H. Kirton. 1988. Effects of selection for divergent ultrasonic fat depth on progeny fatness. Anim. Prod. **47**:379-386.

Butterfield, R. M. 1988. New Concepts of Sheep Growth, Griffin Press Ltd., Netley, South Australia, 168 pp.

Cameron, N. D., and J. Bracken. 1992. Selection for carcass lean content in a terminal sire breed of sheep. Anim. Prod. **54**:367-377.

Dodd, C. J., R. W. Purchas, and G. L. Bennett. 1986. Lean lamb selection: a manual of procedures. MAF Advisory Services Division, Wellington, NZ, 23 pp.

Dýmundsson, O. R. 1987. Advancement of puberty in male and female sheep. New Techniques in Sheep Production I.F.M Marai and J. B. Owen, eds. Butterworths, London, pp 65-78.

Fourie, P. D., A. H. Kirton, and K. E. Jury. 1970. Growth and development of sheep II. Effect of breed and sex on the growth and carcass composition of the Southdown and Romney and their cross. N.Z. J. of Agr. Res. **13**:753-770.

Gallivan, C., and S. Hosford. 1997. Environmental effects on weight, ultrasonic muscle depth and ultrasonic fat depth in Alberta Suffolk lambs. Proc. Annual Meet. Canadian Soc. of Anim. Sci., July 24-26, Montréal, Québec.

Gilmour, A. R., A. F. Luff, N. M. Fogarty, and R. Banks. 1994. Genetic parameters for ultrasound fat depth and eye muscle measurements in live Poll Dorset sheep. Aust. J. Agric. Res. **45**:1281-1291.

Hamlin, K. E., R. D. Green, T. L. Perkins, L. V. Cundiff, and M. F. Miller. 1995. Real-time ultrasonic measurement of fat thickness and Longissimus muscle area: I. Description of age and muscle weight effects. J. Anim. Sci. **73**:1713-1724.

Hammond, J. 1932. Growth and Development of Mutton Qualities in the Sheep. Oliver and Boyd, Edinburgh.

Hopkins, D. L., K. L. Pirlot, A. H. K. Roberts, and A. S. Beattie. 1993. Changes in fat depths and muscle dimensions in growing lambs as measured by real-time ultrasound. Aust. J. Exp. Agric. **33**:707-712.

Hopkins, D. L., D. G. Hall, and A. F. Luff. 1996. Lamb carcass characteristics 3. Describing changes in carcasses of growing lambs using realtime ultrasound and the use of these measurements for estimating the yield of saleable meat. Aust. J. Exp. Agric. **36**:37-43.

Jensen, N. E. 1990. Performance test of ram lambs 1990. Report 684, National Institute of Animal Science, Denmark, 44 pp.

Jury, K. E., P. D. Fourie, and A. H. Kirton. 1977. Growth and development of sheep IV. Growth of the musculature. N. Z. J. Agric. Res. **20**:115-121.

McClelland, T. H., B. Bonaiti, and S. C. S. Taylor. 1976. Breed differences in body composition of equally mature sheep. Anim. Prod. **23**:281-293.

MLC. 1987. *Sheep Yearbook*. Meat and Livestock Commission, Milton Keynes, UK, p. 49-58.

Nicoll, G. B., M. J. Alderton, D. D. Addandale, I. D. Coleman, T. J. Grimwood, and J. A. Thomson, 1992. A terminal sire breeding programme based on screening for hogget liveweight. Proc. N.Z. Soc. Anim. Prod. **52**:125-127.

Olesen, I. and J. O. Husabø. 1994. Effect of using ultrasonic muscle depth and fat depth on the accuracy of predicted phenotypic and genetic values of carcass traits on live ram lambs. Acta Agric. Scand. Sect. A. **44**:65-72.

Pálsson, H. 1939. Meat qualities in the sheep with special reference to Scottish breeds and crosses. J. Agr. Sci. Camb. **29**:544-625.

SAS Institute Inc. 1994. SAS/STAT® Software: Changes and Enhancements, Release 6.10, Cary, NC, 121 pp.

Shrestha, J.B., J.A. Vesley, and J.P. Chesnais. 1985. Genetic and phenotypic parameters for gain and body weights in Suffolk lambs. Can. J. Anim. Sci. **65**:575-582.

Simm, G., C. Alliston, and R. A. Sutherland. 1983. A comparison of live-animal measurements for selecting lean beef sires. Anim. Prod. **37**:211-219.

Stanford, K., I. Clark, and S. D. M. Jones. 1995. Use of ultrasound in prediction of carcass characteristics in lambs. Can. J. Anim. Sci. **75**:185-189.

Stanford, K., C. M. Woloschuk, L. A. McClelland, S. D. M. Jones, and M. A. Price. 1997. Comparison of objective external carcass measurements and subjective conformation scores for prediction of lamb carcass quality. Can. J. Anim. Sci. **77**:217-223.

Turner, J. W., L. S. Pelton, and H. R. Cross. 1990. Using live animal ultrasound measures of ribeye area and fat thickness in yearling Hereford bulls. J. Anim. Sci. **68**:3502-3507.

Whittaker, A. D., B. Park, B. R. Thane, R. K. Miller, and J. W. Savell. 1992. Principles of ultrasound and measurement of intramuscular fat. J. Anim. Sci. **70**:942-952.

Wilson, D. E. 1992. Application of ultrasound for genetic improvement. J. Anim. Sci. **70**: 973-983.

Table 4.1. Ingredients (kg tonne^{-1}) and analysis (%) of the creep feed and lamb-grower diets

Ingredients	Creep Feed	Lamb Grower
Barley grain, whole	477.6	783.6
Alfalfa-dehy	200.0	160.0
Distillers' grains	40.0	-
Soybean meal	105.0	-
Beet pulp	130.0	-
Sheep mineral[a]	10.5	10.0
Dicalcium phosphate	3.0	6.0
Calcium carbonate	3.5	5.0
Ammonium chloride	-	5.0
Molasses, beet	20.0	20.0
Perma-pel[b]	10.0	10.0
Vitamin A, D, E[c]	.25	.25
Deccox[d]	.13	.13
Analysis		
Dry matter (%)	90.5	90.8
Crude protein (%)	18.7	14.5
Acid detergent fibre (%)	15.5	12.3

[a]Contained 93.1% NaCl; 0.55% Mg; 0.33%Zn; 0.27% Mn; 0.03% Cu; 0.005% Se.
[b]Feed pellet binder (Georgia Pacific, Bellingham WA).
[c]Contained 10,000 IU g^{-1} vitamin A; 1250 IU g^{-1} vitamin D; 10 IU g^{-1} vitamin E.
[d]Contained 60 g kg^{-1} decoquinate (Rhône-Poulenc Canada, Mississauga ON).

Table 4.2. Mean, standard deviation, minimum and maximum values of age, weight, and ultrasound measurements[a] of fat depth over the longissimus and longissimus dimensions for the first ultrasound measurement after birth and the last ultrasound measurement prior to slaughter.

First ultrasound measurement after birth	Mean	SD[b]	Minimum	Maximum
Age (d)	9.3	3.7	3.0	14.0
Live weight (kg)	7.8	1.4	4.5	11.5
Longissimus area (cm^2)	2.8	.9	1.1	4.6
Longissimus depth (cm)[c]	1.2	.2	.5	1.7
Longissimus width (cm)[d]	2.9	.6	1.9	3.9
Fat depth over longissimus (cm)[e]	.2	.5	.0	.4
Last ultrasound measurement				
Age (days)	159.5	9.9	134.0	185.0
Weight (kgs)	44.8	2.6	40.4	73.0
Longissimus area (cm^2)	13.7	1.5	10.4	17.3
Longissimus depth (cm)	32.7	1.3	22.0	46.4
Longissimus width (cm)	58.3	2.3	46.0	68.0
Fat over longissimus (cm)	5.0	1.8	2.2	9.1

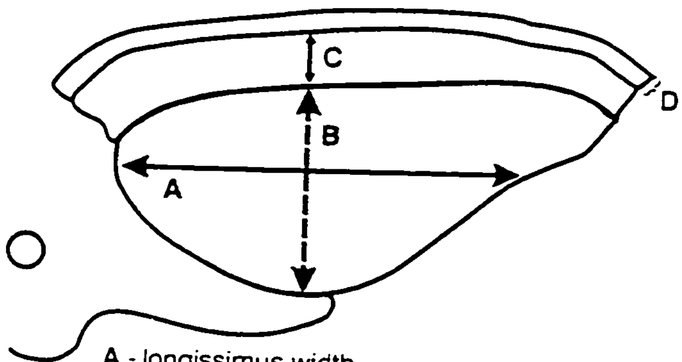
[a]All ultrasound measurements at the first lumbar vertebra.
[b]SD, standard deviation.
[c]Longissimus depth, equivalent to the 'B' measurement of Pálsson (1939).
[d]Longissimus width, equivalent to the 'A' measurement of Pálsson (1939).
[e]Fat depth over longissimus, equivalent to the 'C' measurement of Pálsson (1939).

Table 4.3. Reduced[a] equations for prediction of ultrasound longissimus and fat measures from age in days, age^2, live weight and liveweight^2

Prediction[b]	Sex	R^2	RSD	Equation
Longissimus area (LEA) cm^2	ram	.81	1.48	REA = .07 age + 2.73
LEA	ewe	.77	1.60	REA = .06 age + 2.77
Ribeye depth (B) mm	ram	.76	.28	B = .01 age + 1.28
B	ewe	.73	.29	B = .01 age + 1.29
Longissimus width (A) mm	ram	.75	.47	A = .02 age + 3.28
A	ewe	.73	.53	A = .02 age + 3.15
Fat over longissimus (C) mm	ram	.63	.08	C = .002 age + .077
C	ewe	.66	.07	C = .002 age + .067

[a]In regressions with age, age^2, wt, wt^2 in the model, for all predictions (LEA, A. B, C) age was the only significant predictor ($P < 0.15$).
[b]All measurements made at first lumbar vertebra.

Figure 4.1. Ultrasound measurement of longissimus muscle dimensions and subcutaneous fat thickness at the first lumbar vertebra



A - longissimus width
B - longissimus depth
C - subcutaneous fat thickness
D - thickness of hide

Shaded region is cross-sectional area of the longissimus muscle

All measurements made at the first lumbar vertebra

Figure 4.2. Liveweight of lambs from 15 to 180 d of age

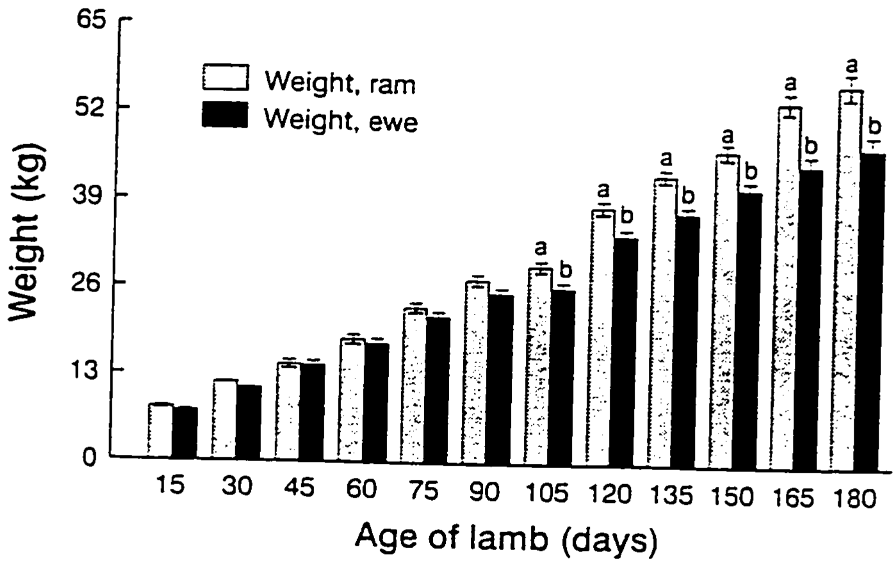


Figure 4.3. Changes in size of longissimus area by sex and age. Actual areas and areas after adjustment for liveweight.

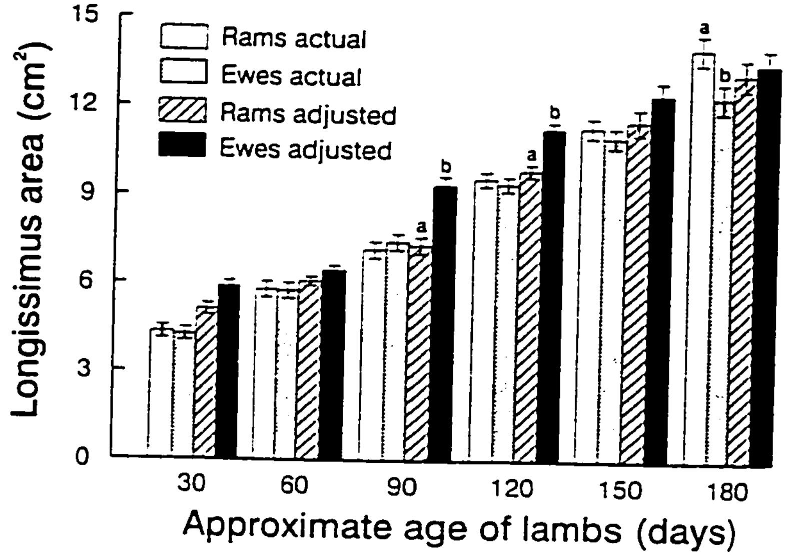


Figure 4.4. Changes in size of longissimus width 'A' by sex and age. Actual widths and widths after adjustment for liveweight.

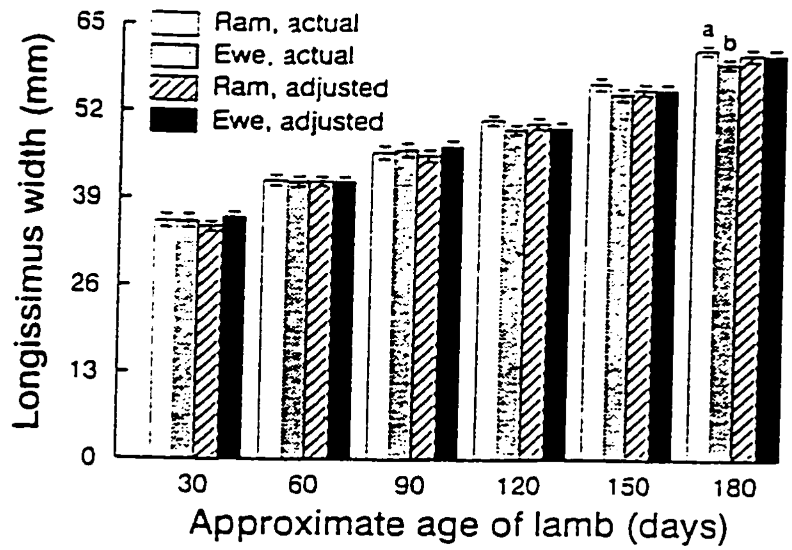


Figure 4.5 Changes in size of longissimus depth 'B' by sex and age. Actual values and values after adjustment for liveweight.

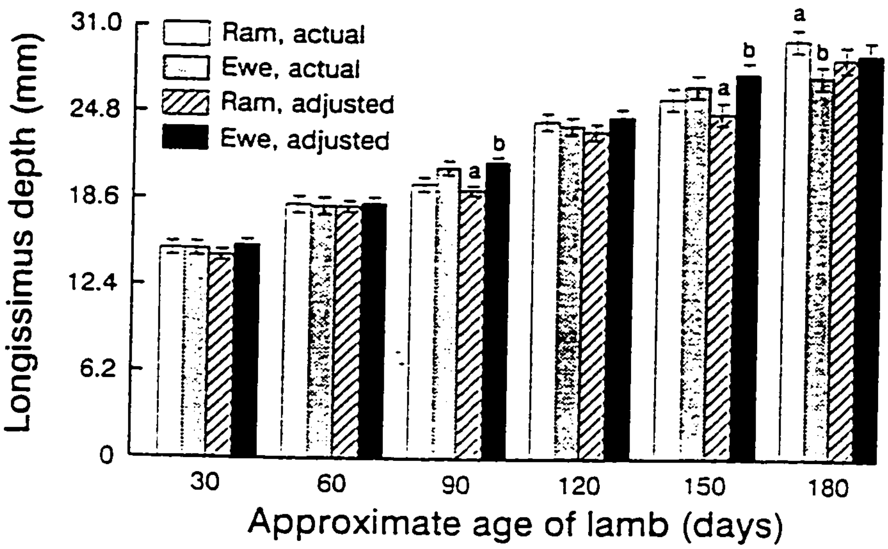
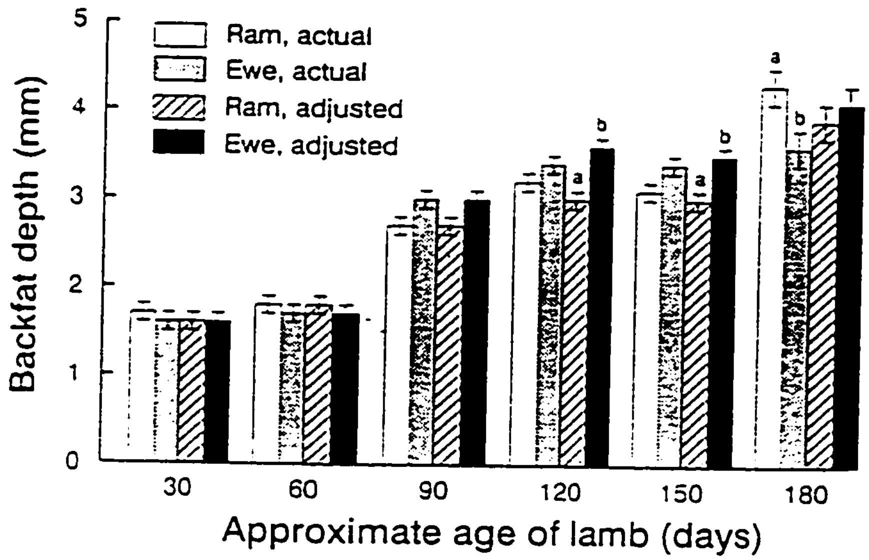


Figure 4.6. Changes in backfat depth 'C' by sex and age. Actual values and values after adjustment for liveweight.



CHAPTER 5

Comparison of objective external carcass measurements and subjective conformation scores for prediction of lamb carcass composition.

5.1 Introduction

Many attempts have been made to find rapid, inexpensive and accurate methods to estimate carcass composition from intact carcasses. Numerous external and internal carcass measurements have been investigated to determine their usefulness in predicting lamb carcass composition (Pálsson 1939; Timon and Bichard 1965; Riley and Field 1969). However, these studies were unsuccessful in identifying the single measurement or set of measurements that would classify lamb carcass composition with acceptable precision. More recently, Kempster et al. (1976) and Kirton et al. (1992) determined that subjective scoring of lamb carcasses for fatness was a more precise predictor of carcass composition than were linear carcass measurements, although problems inherent with subjective carcass evaluation, such as difficulty maintaining standards within and between graders, were noted. In contrast, Jones et al. (1992) found that the precision of visual assessment of lamb carcasses for the prediction of lean content was low, compared to tissue depth measurements between the 12th and 13th ribs.

In Canada, federally inspected lamb carcasses are currently classified on the basis of saleable meat yield by a combination of GR measurement and subjective conformation scores for the region of the leg, loin and shoulder (Jones et al. 1993). The subjective

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conformation scores are on a five point scale in which a score of one indicates a severe lack of muscling and a score of five indicates excellent muscling. As the Canadian Classification System for lamb is relatively new, the impact of the system on the marketing of lamb has not yet been determined. Recently, members of the Canadian sheep industry have expressed some concerns about the subjective conformation score system. This study was conducted to address some of these concerns by (1) determining if an unjustified bias against certain sexes or breeds of lambs exists in the subjective conformation score system and (2) comparing the accuracy and precision of objective external carcass measurements with that of subjective conformation scores in determining saleable meat yield.

5.2 Materials and methods

Over a period of two years, data were collected on 1,397 lambs of known sex and breed types and 108 lambs of unknown sex and breed type slaughtered at Canada West Foods (Alberta) Corp., Innisfail, AB. Rams, ewes and wethers were studied and were classified by type (meat- or wool-). The meat-type lambs were classified by frame size (light, medium or large) (Table 5.1). Large frame lambs included those of Suffolk and Canadian Arcott breeding; medium frame included Dorset, Katahdin, North Country Cheviot, Polypay, Texel and Rideau Arcott lambs; and light frame included Romanov and Finn lambs. Wool-type included lambs of Rambouillet and Columbia breeding.

Warm carcass weight was determined approximately 35 min after stunning. Carcasses were then chilled for a minimum of 1 h at 5°C prior to collection of carcass measurements. All measurements, performed by a single technician, were made on the right side of the hanging carcass. Carcass length (L), leg circumference (G) and leg length (T) were measured using a vinyl measuring tape. Depth of the leg (H) was determined using metal calipers. All carcass measurements were collected for all lambs in the study with the exception of H, which was measured only in the second year of the study, on a total of 919 carcasses. The carcass measurements recorded and their symbols are essentially those of Pálsson (1939) and Timon and Bichard (1965) and are described in detail in Table 5.2. Subjective conformation scores for the leg, loin and shoulder region and GR (Kirton et al. 1984) were determined by Agriculture and Agri-Food Canada graders on carcasses chilled for 3 to 6 h at 5°C.

Saleable meat yield was determined by dissecting 69 of the lambs into primal cuts. Additional lambs were chosen, but later proved to be unavailable for carcass dissection due to the marketing demands of the commercial lamb processing plant. The primal cuts included a square (bone-in) shoulder, short cut leg, loin and rack and were trimmed to have no more than 0.64 cm of subcutaneous fat. For other lambs, saleable meat yield (%) was estimated using the equation of Jones et al. (1993):

$$\text{Saleable yield} = 78.92 - 0.51\ \text{GR} + 1.25\ \text{ASM}$$

where ASM is the average of the three subjective conformation scores rounded to the nearest integer. This equation has an R^2 of 0.56 and an RSD of 1.3%. All statistical analyses were performed using the stepwise option of the REG procedure and the GLM and CATMOD procedures of the SAS Institute, Inc. (1988). Stepwise regression was used to assess the accuracy of carcass measurements in predicting saleable meat yield and carcass characteristics from cut-out. Analysis of variance was used to determine the effects of breed type, frame size and sex on carcass measurements. Analysis of variance for categorical data was used to determine the effects of breed, sex and a breed by sex interaction on the assignment of subjective conformation scores. Carcass cut-out measurements were adjusted by cold carcass weight, while conformation scores were expressed for carcases adjusted to the same GR.

5.3 Results and discussion

The vast majority of lambs classified under the Canadian System are recognized to have conformation scores ranging from two to four (Stanford et al. 1995). In the present study, although carcass measurements were collected on a large number of lambs (n = 1505), the number of lambs with overall conformation scores of one and five were also very low (n = 1 and n = 2, respectively). Therefore, results are reported for conformation scores of two, three and four, only. Relationships between subjective conformation scores and objective carcass measurements are shown in Table 5.3. The results of this study confirm the findings of Kirton and Pickering (1967), Jackson and Mansour (1974) and Lirette et al. (1984), namely that carcasses of good conformation had a more compact trunk and shorter hind limbs than those of poorer conformation. In the present study, carcass length and leg length decreased ($P < 0.05$) with increasing conformation score for the regions of the leg, loin and shoulder. In contrast, leg circumference and leg depth increased ($P < 0.05$) with increasing leg score. The relationship between these measurements and loin and shoulder score, however, was less clear. This study confirms the accuracy of the subjective conformation score system in identifying compact, muscular carcasses. This should be of value, given that consumers tend to prefer cuts of meat from compact "blocky" carcasses with thicker muscles (Jackson and Mansour 1974; Harrington and Kempster 1989).

Not all breed types and frame sizes had the blocky carcasses favoured by the subjective conformation system. The effect of breed type and frame size on external carcass measurements is shown in Table 5.4. Light-frame lambs had a lower leg circumference and leg depth ($P < 0.05$) than the other lamb types in this study, while having a longer carcass than medium-frame lambs ($P < 0.05$) and a longer leg than both large- and medium-frame lambs ($P < 0.05$). Wool-breed lambs had a longer carcass than large- and medium-frame lambs ($P < 0.05$) and the longest leg of all lambs on the study ($P < 0.05$), although their leg circumference and leg depth tended to be lower than that of large frame lambs.

Gender effects on external carcass measurements are shown in Table 5.4. Gender had less of an effect on carcass conformation than did breed type. Rams had longer carcasses ($P < 0.001$) and a greater leg length ($P < 0.05$) than ewes and wethers, but there were no significant differences between the genders in leg circumference or leg depth. Rams, with the exception of the light-frame and wool-breed lambs, had a better shoulder conformation score than ewes and wethers ($P < 0.05$), but wethers and ewes with the exception of medium-frame lambs had better loin scores than rams ($P < 0.001$). As overall conformation score is based on the average of the scores for the leg, loin and shoulder rounded to the nearest integer (Jones et al. 1993), the combination of these gender-related traits resulted in similar overall conformation scores for both sexes. In contrast, Notter et al. (1991) found that wethers had better leg and overall conformation than ewes, while no differences were found in conformation or carcass quality between rams and wethers, other than a leaner carcass for rams. In the present study, lambs ranged in age from 3 to 11 months and were of wide-ranging breed type/frame size. Notter et al. (1991) compared lambs of less than 6 months of age, which would account for the lack of difference in conformation between wethers and rams.

Comparing the subjective conformation scores from Table 5.5 against frame size revealed that wool-breeds and light-frame lambs had lower scores for the leg and loin than did medium- and large-frame lambs ($P < 0.01$), in accordance with the work of

Crouse et al. (1981). Those researchers found Rambouillet-sired lambs to have inferior leg conformation scores compared to Suffolk-sired lambs. Medium-frame lambs in the present study had higher shoulder scores than large-frame lambs which in turn had higher shoulder scores than light-frame and wool- breed lambs ($P < 0.05$). Light-frame rams in this study as in that by Lirette et al. (1984), were found to have the lowest conformation scores of all breed types and frame sizes ($P < 0.05$). Producers of light-frame lambs should therefore consider castration of their male lambs in order to improve carcass conformation and marketability.

The usefulness of subjective conformation scores in the prediction of saleable or lean meat yield in lambs has been controversial. Horgan et al. (1995), Wolf et al. (1981) and Kempster et al. (1981) found subjective conformation to be of limited value in predicting saleable and/or lean meat yield, in direct contrast to the work of Kirton et al. (1992) and Jones et al. (1993). An explanation for this discrepancy may be found in the populations of lambs evaluated in these studies: the more variance in lamb breed types and sizes used, the greater the value of subjective conformation score in predicting lean and/or saleable meat yield. Consistent with that trend, subjective conformation scores were useful in predicting saleable meat yield in the present study which involved lambs of widely ranging breed types and carcass weights. Lambs of poorer conformation were generally found to have a reduced saleable meat yield. Saleable meat yield as determined by carcass dissection was lower from wool-breeds than from large-frame lambs ($P < 0.05$) of the same carcass weight and tended to be lower from light-frame than from medium- or large-frame lambs (Table 5.6), although number of medium- and light-frame lambs dissected was low. A trend toward reduced meat yield from Rambouillet-sired as compared to Suffolk-sired lambs was also reported by Crouse et al. (1981). Because light frame and wool-breed carcasses lack the compact blocky conformation desired by consumers, the meat from these lambs might be better directed toward end uses such as cubed or ground lamb which are not influenced by conformation.

A number of researchers (Kirton and Pickering 1967; Jackson and Mansour 1974; Kempster et al. 1981) have concluded that lamb carcasses with good conformation tend to be fatter than those with poor conformation. In an earlier study (Stanford et al. 1995) we also showed a trend toward increasing GR measurement with increasing conformation score under the Canadian Classification System. However, any tendency to reward carcass fatness through subjective conformation score is, in practice, balanced by penalties for excessive GR measurement. The most desirable carcasses have a high conformation score and a low GR measurement.

The results of this study demonstrate that the subjective conformation system lacks an inherent unfair bias against breed types or frame sizes. Light-frame and wool-breeds lamb carcasses are assigned lower conformation scores than large- or medium-frame carcasses, but these lower scores are justified by their reduced saleable meat yields determined by dissection as well as a poorer conformation determined by objective measurements (lower leg circumference and increased carcass length). An earlier study, Stanford et al. (1995), showed that ultrasound measurements could not accurately predict subjective conformation scores. The relationships between objective carcass measurements and subjective conformation scores are shown in Table 5.7. Although the predictive value of carcass measurements is superior to that of ultrasound (Stanford et al. 1995), less than 50% of the variation in conformation scores could be explained by carcass measurements. Certain trends, though, are evident. Shoulder conformation score was most accurately predicted by carcass weight and carcass length. Loin conformation score was best predicted by GR measurement and by the ratio between carcass length and leg depth, other than for light-frame lambs, for whom loin conformation score was best predicted by GR and a ratio of leg length and leg circumference. In contrast, the best predictors of leg conformation score varied according to lamb breed type and frame size. These results are supported by those of Kempster et al. (1976), who found prediction equations for the shoulder to be stable across lamb breed type while those for the leg were highly influenced by lamb breed type, perhaps due to variations between breed types in fat distribution in the hind leg.

Equations for calculating carcass characteristics from carcass measurements are shown in Table 5.8. The carcass measurements used in this study had a reduced accuracy (R^2 = 0.45, RSD = 1.6%) compared to subjective conformation scores (R^2 = 0.56, RSD=1.3%, Jones et al. 1993) when used to predict saleable meat yield as currently measured in the Canadian Classification System for lamb. However, prediction of saleable meat yields (from carcass dissection) by carcass measurements was slightly improved (R^2 = 0.61, RSD=1.3%) over that by subjective conformation scores. For the primal cuts, carcass measurements were highly accurate in predicting percentage of the leg (R^2 = 0.80, RSD = 0.6%). For the other primal cuts, GR measurement was the only significant predictor ($P < 0.15$) of percentage of shoulder, and there were no significant predictors ($P > 0.15$) for percentage of loin. In the present study, the majority of the carcass measurements focussed on the leg, but other carcass dimension measurements would permit more accurate prediction of the percentage of the carcass in the loin and shoulder primals. The results of this study demonstrate that objective carcass measurements would have a marginally superior accuracy for predicting saleable meat yield than the subjective conformation scores currently in use in the Canadian Classification System for Lamb. The objective measurements used in this study however, required 3 min per carcass. By comparison, the assignment of subjective conformation scores, required less than 20 sec per carcass by a trained Agriculture and Agri-Food Canada grader (T. Coupland, pers. commun., 1995). The carcass measurements used in this study are slow and labor intensive, which prevents their practical application in commercial lamb processing facilities. However, a new technology, video image analysis, offers objective, rapid, automated measurement of numerous regions of the carcass. Studies are currently in progress to assess the use of video image analysis for classification of Canadian lamb carcasses.

5.4 References

Crouse, J. D., Busboom, J. R., Field, R. A. and Ferrell, C. L. 1981. The effects of breed, diet, sex, location and slaughter weight on lamb growth, carcass composition and meat flavor. J. Anim. Sci. **53:** 376-386.

Harrington, G. and Kempster, A. J. 1989. Improving lamb carcass composition to meet modern consumer demand. Pages 79-90 *in* O. Dyrmundsson and S. Thorgiersson, eds. Agriculture Research Institute, Reykjavik, Iceland.

Horgan, G. W. , Murphy, S. V. and Simm, G. 1995. Automatic assessment of sheep carcasses by image analysis. Anim. Sci. **60:** 197-202.

Jackson, T. H. and Mansour, Y. A. 1974. Differences between groups of lamb carcasses chosen for good and poor conformation. Anim. Prod. **19:** 93-105.

Jones, S. D. M., Jeremiah, L. E., Tong, A. K. W., Robertson, W. M. and Gibson, L. L. 1992. Estimation of lamb carcass composition using an electronic probe, a visual scoring system and carcass measurements. Can. J. Anim. Sci. **72**: 237-244.

Jones, S. D. M., Robertson, W. M. and Price, M. A. 1993. The assessment of saleable meat yield in lamb carcasses. Int. Congr. Meat Sci. Technol. Calgary, AB p. 190 (Abstr.).

Kempster, A. J., Avis, P. R. D., Cuthbertson, A. and Harrington, G. 1976. Prediction of the lean content of lamb carcasses of different breed types. J. Agric. Sci. (Camb.) **86**: 23-34.

Kempster, A. J., Croston, D. and Jones, D. W. 1981. Value of conformation as an indicator of sheep carcass conformation within and between breeds. Anim. Prod. **33:** 39-49.

Kirton, A. H. and Pickering, P. S. 1967. Factors associated with differences in carcass conformation in lambs. N. Z. J. Agr. Res. **10:** 183-200.

Kirton, A. H., Woods, E. G. and Duganzich, D. M. 1984. Predicting the fatness of lamb carcasses from carcass wall thickness measured by a ruler or by a Total Depth Indicator

(TDI) probe. Livest. Prod. Sci. **11**: 185-194.

Kirton, A. H., Mercer, G. J. K. and Duganzich, D. M. 1992. A comparison between subjective and objective (carcass weight plus GR or the Hennessy Grading Probe) methods for classifying lamb carcasses. Proc. N.Z. Soc. Anim. Prod. **52**: 41-43.

Lirette, A., Seoane, J. R., Minvielle, F. and Froehlich, D. 1984. Effects of breed and castration on conformation, classification, tissue distribution, composition and quality of lamb carcasses. J. Anim. Sci. **58:** 1343-1357.

Notter, D. R., Kelly, R. F. and McClaugherty, F. S. 1991. Effects of ewe breed and management system on efficiency of lamb production: II Lamb growth, survival and carcass characteristics. J. Anim. Sci. **69:** 22-33.

Pálsson, H. 1939. Meat qualities in the sheep with special reference to Scottish breeds and crosses. J. Agr. Sci. (Camb.) **29**: 544-625.

Riley, M. L. and Field, R. A. 1969. Predicting carcass composition of ewe, wether and ram lambs. J. Anim. Sci. **29**: 567-572.

SAS Institute, Inc. 1988. SAS User's Guide: Statistics. Version 6.03 ed. SAS Institute Inc, Cary, NC. 956 pp.

Stanford, K., Clark, I. and Jones, S. D. M. 1995. Use of ultrasound in prediction of carcass characteristics in lambs. Can. J. Anim. Sci. **75:** 185-189.

Timon, V. M. and Bichard, M. 1965. Quantitative estimates of lamb carcass composition 3. Carcass measurements and a comparison of the predictive efficiency of sample joint composition, carcass specific gravity determinations and carcass measurements. Anim. Prod. **7**: 189-201.

Wolf, B. T., Smith, C., King, S. W. B. and Nicholson, D. 1981. Genetic parameters of growth and carcass composition in crossbred lambs. Anim. Prod. **32:** 1-7.

Table 5. 1. Minimum, maximum and mean carcass weight of lambs by sex and type

Sex	n	Frame	Carcass weight (kg) Minimum	Maximum	Mean	SD[z]
Ram	209	large	16.1	34.1	23.5	2.6
	187	medium	16.0	29.7	22.5	2.4
	36	light	19.2	29.9	22.9	2.1
	51	wool-breed	19.8	26.9	23.0	1.7
Ewe	221	large	16.2	30.5	23.3	2.4
	136	medium	16.3	36.2	23.6	2.8
	56	light	18.7	30.5	23.9	2.0
	76	wool-breed	19.0	31.2	24.0	2.2
Wether	214	large	16.1	32.1	23.9	3.0
	131	medium	17.3	28.9	22.8	2.7
	40	light	20.7	27.0	23.7	1.6
	40	wool-breed	18.1	35.1	23.7	2.6
Total	1397[y]					

[z]SD, standard deviation of the mean.

[y]Carcass measurements were collected for an additional 108 lambs of unknown sex and breed type.

Table 5. 2. Description of external carcass measurements

Measurement	Symbol	Definition
a) Linear measurements		
Carcass length (cm)	L	Spine of scapula to the distal end of the tarsals
Length of leg (cm)	T	Tubercle on the proximal end of the tibia to the distal end of the tarsals
b) Caliper measurement		
Depth of leg (cm)	H	Maximum width between the most caudal point on the median plane between the legs to the distal edge of the biceps femoris
c) Circumference measurement		
Leg circumference (cm)	G	Maximum circumference of a line passing over the distal end of the iliac wings of the pelvis and the most caudal point on the median plane between the legs

Table 5.3. Relationship between subjective conformation scores and objective measurements for lamb carcasses adjusted to the same GR

Conformation Score	Carcass Measurement			
	T Leg Length (cm)	L Carcass Length (cm)	G Leg Circ. (cm)	H Leg Depth (cm)
Leg Score				
2	31.6^{a}	107.3^{a}	40.6^{a}	23.6^{a}
3	31.3^{a}	106.3^{b}	41.4^{b}	23.9^{b}
4	30.4^{b}	104.8^{c}	41.8^{c}	24.3^{c}
SEM^{z}	0.2	0.3	0.2	0.1
Loin Score				
2	31.9^{a}	107.8^{a}	41.2	23.9^{ab}
3	30.8^{b}	105.5^{b}	41.3	23.8^{a}
4	30.6^{b}	105.0^{b}	41.3	24.2^{b}
SEM	0.2	0.4	0.2	0.1
Shoulder score				
2	31.5^{a}	107.0^{a}	41.3	23.9
3	31.1^{a}	106.2^{a}	41.2	23.9
4	30.7^{b}	105.2^{b}	41.3	24.0
SEM	0.2	0.3	0.2	0.1

^{z}SEM, standard error of the mean.

^{abc}Means in the same column followed by different superscripts differ ($P < 0.05$).

Table 5.4. Effect of frame size, breed type and sex on external carcass measurements (n = 1397)

Frame size/sex	Carcass Length (L) cm	SEM[y]	Leg Length (T) cm	SEM	Leg Circum. (G) cm	SEM	Leg Depth[z] (H) cm	SEM
Large	104.4^{a}	0.3	29.6^{a}	0.1	41.1^{a}	0.2	23.9^{a}	0.2
Medium	100.9^{b}	0.5	28.7^{b}	0.2	40.8^{a}	0.3	23.4^{a}	0.2
Light	105.0^{ac}	0.4	30.4^{c}	0.2	39.3^{b}	0.2	22.7^{b}	0.4
Wool breed	105.8^{c}	0.5	31.1^{d}	0.2	40.6^{a}	0.3	23.4^{a}	0.2
Ram	105.1^{a}	0.2	30.3^{a}	0.1	40.6	0.1	23.9	0.1
Ewe	103.3^{b}	0.3	29.8^{b}	0.2	40.5	0.2	24.0	0.2
Wether	103.6^{b}	0.3	29.9^{b}	0.1	40.6	0.1	24.0	0.2

[z]Data collected in year 2 of study only (n = 919). Leg depth data do not include medium or light- frame wethers.

[y]SEM, standard error of the mean

[abcd]Means in the same column (across frame size or across sex) followed by different superscripts differ ($P < 0.05$), with the exception of carcass length within sex which differ ($P < 0.001$)

Table 5.5. Effect of sex within frame size and sex on subjective conformation score from categorical analysis of variance

Frame	Sex	Leg score	SEM[z]	Loin score	SEM	Shoulder score	SEM
Large	Ram	3.19[a]	0.04	3.14[a]	0.04	3.22	0.05
	Ewe	3.26[b]	0.03	3.19[ab]	0.03	3.14	0.03
	Wether	3.26[b]	0.03	3.28[b]	0.04	3.13	0.03
Medium	Ram	3.20	0.04	3.22	0.04	3.35[a]	0.05
	Ewe	3.21	0.04	3.22	0.04	3.19[b]	0.04
	Wether	3.22	0.05	3.21	0.04	3.17[b]	0.04
Light	Ram	2.76[a]	0.08	2.76[a]	0.08	2.86[a]	0.10
	Ewe	3.00[b]	0.05	3.23[b]	0.06	3.04[ab]	0.05
	Wether	2.98[b]	0.08	3.15[b]	0.07	3.13[b]	0.07
Wool	Ram	2.94	0.07	2.94	0.07	3.00	0.08
	Ewe	2.94	0.06	3.11	0.06	3.05	0.06
	Wether	2.94	0.04	3.11	0.03	3.04	0.04

[z]SEM, standard error of the mean.

[ab]Means in the same column within the same frame size followed by different superscripts differ ($P < 0.001$ for loin score and $P < 0.05$ for other scores).

Table 5.6. Effect of breed type and frame size on carcass cut-out data adjusted to equal carcass weight.

				Primal cuts					
		Saleable		Leg		Loin		Shoulder	
Frame /type	n	Yield (%)	SEM[z]	Wt (kg)	SEM	Wt (kg)	SEM	Wt (kg)	SEM
Large	23	78.78^{a}	0.01	5.51^{a}	0.05	5.63^{a}	0.07	6.29^{a}	0.08
Medium	2	77.66^{ac}	0.02	5.19^{abc}	0.19	5.94^{a}	0.23	5.51^{b}	0.26
Light	5	76.94^{ac}	0.01	4.82^{b}	0.04	5.07^{b}	0.15	5.57^{b}	0.16
Wool breed	39	76.99^{bc}	0.01	5.29^{c}	0.12	5.67^{a}	0.05	6.14^{a}	0.06

[z]SEM, standard error of the mean.

[abc]Means in the same column followed by different superscripts differ ($P < 0.05$).

Table 5. 7. Partial correlations between subjective conformation scores and carcass measurements by lamb frame size and breed type from stepwise regression

	Classification variable[z]											
	Leg conformation Breed type				Loin Conformation Breed type				Shoulder Conformation Breed type			
	Large	Med.	Light	Wool	Large	Med.	Light	Wool	Large	Med.	Light	Wool
GR	NS	NS	NS	NS	0.16	NS	0.11	0.07	0.02	NS	NS	0.05
Carcass wt.	NS	0.03	0.14	NS	0.02	NS	NS	NS	0.11	0.17	0.22	NS
Leg circ. (G)	NS	0.02	NS	0.04	0.03	NS	NS	NS	NS	NS	NS	0.11
Length (L)	NS	0.05	NS	NS	0.06	NS	NS	NS	0.09	0.19	0.23	0.15
Leg length (T)	NS	0.03	NS	NS	0.03	NS	NS	NS	NS	NS	NS	NS
Leg depth (H)	NS	0.08	NS	NS	0.02	NS	NS	NS	NS	NS	NS	NS
L / H	NS	NS	NS	0.21	0.07	0.18	NS	0.28	NS	NS	NS	NS
T / H	0.27	0.09	NS	NS	NS	NS	NS	0.03	0.02	NS	NS	NS
L / G	NS	0.03	0.38	NS	0.03	NS	NS	0.04	NS	NS	NS	NS
T / G	NS	0.16	NS	NS	0.01	NS	0.30	NS	NS	NS	NS	NS

[z]partial R^2

NS, not significant ($P > 0.15$).

Table 5.8. Equations for calculating carcass characteristics from carcass measurements

	Predicted variable			
			Primal cuts[z]	
Regression Coefficients	Saleable meat yield(%)[y]	Saleable meat yield (%)[x]	Leg (%)[x]	Shoulder (%)[x]
Intercept	34.94	32.90	-27.12	27.11
GR	NI	-0.21	NS	-0.17
Carcass length (L)	-0.03	NS	NS	NS
Leg length (T)	NS	NS	NS	NS
Leg circumference (G)	0.45	7.89	4.68	NS
Leg depth (H)	NS	NS	NS	NS
T / H	-4.92	NS	NS	NS
T / G	16.94	NS	0.51	NS
L / carcass weight[w]	3.49	3.69	3.17	NS
R^2	0.45	0.61	0.80	0.36
RSD	1.6	1.3	0.6	1.2

[z] No significant predictors for loin (%), (P >0.15)

[y]Determined from equation (Jones et al. 1993).

[x]Determined from carcass cut-out (n = 69) and expressed as a percentage of cold carcass weight.

[w]Warm carcass weight.

NI, not included in analysis

NS, not significant (P > 0.15).

CHAPTER 6

Video image analysis for on-line classification of lamb carcasses

6.1 Introduction

As with a number of other countries in recent years, livestock grading was privatized in Canada during 1996, a move which has added impetus to the search for new, more cost-efficient livestock-grading technologies, such as video image analysis (VIA).

Video image analysis offers the possibility of accurate, automated carcass grading and is currently a world-wide research focus of the beef (Eldridge and Ball 1992; Jones et al. 1992; Jones et al. 1995; Karnuah et al. 1995; Kuchida et al. 1995) and pork industries (Gregor and Scholz 1993; Webb 1995; Scholz et al. 1995), although reports of its use for sheep grading are limited (Patterson et al. 1994, Horgan et al. 1995).

The equipment required for VIA includes a video camera, controlled lighting of the carcass and computer hardware and software necessary to digitize the video image (Wood et al. 1991). Depending on the system used, VIA can determine the colour and/or shape of a part or whole carcass, and through an appropriate prediction equation, predict meat yield (Jones et al. 1992). Provided that carcasses are sectioned, VIA can also predict intramuscular fat content (Gregor and Scholz 1993; Jones et al. 1995). As the speed of VIA measurement is largely a function of available computer resources, carcasses may be simultaneously classified to several standards in order to determine the most appropriate market.

A version of this chapter has been submitted for publication in Animal Science.

The Meat Research Corporation of Australia has been developing a VIA system, VIAscan®, for carcass grading of beef and lambs since 1989, with a number of trials conducted in Australia to evaluate its potential for grading lambs (Lissiman 1993). The following study was a comparison of the VIAscan® system and the current Canadian Classification System for prediction of meat yield of lamb carcasses, as well as an assessment of the utility of the VIAscan® system under commercial, on-line conditions.

6.2 Materials and methods

Data were collected on 58 lambs randomly selected from 1288 head slaughtered over a 1-week period at a commercial abattoir. Rams, ewes and wethers of either wool-type (Rambouillet, Targhee) or large-frame meat-type (Suffolk, Hampshire) breeding were studied. Warm carcass weight and VIAscan® images were recorded approximately 35 minutes after stunning. Images were collected on a dorsal view of the warm carcass using a fixed video camera and dedicated computer system. Carcasses were suspended in front of a matt black photographic screen and illuminated by two spotlights. Video data included both dimensional (n = 57) and colour variables (n = 36) for each carcass. Two technicians were required to collect the VIA data; one to operate the computer and the other to properly orient and steady the carcasses. Data collection and analysis required approximately 6 seconds per carcass. Thickness of tissue over the 12th rib (GR) was measured with a GR knife and subjective conformation scores for the leg, loin and shoulder region were determined by an Agriculture and Agri-Food Canada grader on carcasses chilled for 3 to 6 h at 5°C. Subjective conformation was estimated on a five-point scale with scores of one and five indicating extremely deficient and excellent muscling, respectively.

Saleable meat yield (Table 6.1) was determined by processing the lamb carcasses into primal cuts. The primal cuts included a square (bone-in) shoulder, short cut leg, loin and rack and were trimmed to have no more than 0.64 cm of subcutaneous fat. Saleable meat yield (%) in the current Canadian Classification System for lamb is estimated using the equation of Jones et al. (1993)

$$\text{Saleable yield} = 78.92 - 0.51\ GR + 1.25\ ASM\ (R^2 = 0.56,\ RSD = 1.3\%)$$

where ASM is the average of the three subjective conformation scores rounded to the nearest integer. All statistical analyses were performed using the stepwise option of the REG procedure and the GLM and PRINCOMP procedures of the SAS Institute, Inc. (1993). Analysis of variance was used to assess the effects of breed type and gender on GR measurement and saleable meat yield. The model included breed-type and gender, with means compared using the least-squares-means. After data were first normalized to have a mean of 0 and standard deviation of 1, principal component analysis was used to determine smaller sets of the VIA variables that would carry most of the original variation in saleable meat yield. Stepwise regression was used to assess the accuracy of the VIA variables and carcass weight in predicting GR measurement, saleable meat yield and percentage of the primal cuts from dissection.

6.3 Results

6.3.1 Breed and gender effects

The study was conducted in March. The majority of lambs available for slaughter at this time were fed in confinement (feedlot) and aged 10 months or greater. As sheep feedlots prefer wethers for ease of management, only a small number of rams and ewes entered the study. Large-frame and wool-breeds lambs did not differ ($P > 0.05$) in saleable meat yield or GR (Table 6.1), but rams had a higher ($P > 0.001$) saleable yield than wethers due to their increased leanness as evidenced by their lower GR.

6.3.2 Principal component analysis

Although the video image analysis data consisted of 93 variables for each carcass, four principal components (Table 6.2) explained 64% of the variation in saleable meat yield. Other principal components explained less than 2% of the variation each, so were excluded from further analysis.

6.3.3 Predictions of saleable meat yield

GR was a more valuable predictor (R^2 = 0.48, RSD = 19 g kg^{-1}) of saleable meat yield than carcass weight (R^2 = 0.28, RSD = 23 g kg^{-1}). Combining the GR and carcass weight did not improve the prediction of saleable meat yield compared to prediction with GR alone. Prediction of saleable meat yield by VIAscan® and carcass weight had increased precision (R^2 = 0.71, RSD = 14.3 g kg^{-1}) compared to prediction of saleable meat yield by conformation score and GR measurement (R^2 = 0.52, RSD = 18.4 g kg^{-1} for this data set). The addition of GR to VIAscan® data only marginally improved prediction of saleable meat yield (R^2 = 0.75, RSD = 13 g kg^{-1}) compared to prediction with VIAscan® and carcass weight. Prediction equations for saleable meat yield and proportions of waste fat and carcass primals are shown in Table 6.3.

Prediction using VIA of the proportion of saleable meat in the high-priced leg cuts (R^2 = 0.71, RSD = 6.6 g kg^{-1}) and in the shoulder (R^2 = 0.62, RSD = 8.8 g kg^{-1}) would have commercial value, although there were no significant predictors (P > 0.15) for the proportion in the loin. The loin primal appears to be a relatively fixed proportion of carcass weight, as the RSD was 13.4 g kg^{-1} for a prediction equation containing an intercept alone.

The equation for GR measurement is not shown in Table 3 due to the large number (n =

25) of variables included. Although prediction of GR from VIA data had a high residual error (R^2 = 0.68, RSD = 2.4 mm), proportions of waste fat and bone dissected from carcasses were accurately predicted (R^2 = 0.62, RSD = 11 g kg^{-1}).

6.4 Discussion

On-line utility of the VIAscan® system

For reasons of confidentiality, a complete description of the variables measured by the VIAscan® system was not available to us. Variables were instead subdivided by colour or shape and classified by the region of the carcass measured. However, the lack of variable description in no way compromised our ability to assess the utility of the VIAscan® system as variables are standardized and would be repeatable, providing the system were operated by trained personnel (Richmond et al. 1995).

Although two technicians were required for collection of VIA data in this study, use of a computerized system for carcass identification and a device to stabilize and properly orient the carcass would automate the image collection process. The VIA system described by Horgan et al. (1995) collected data on both dorsal and lateral views of carcasses 1-day post-slaughter, but would be more difficult to integrate into commercial lamb processing plants than the VIAscan® system due to the requirement for 24 h cold carcass storage prior to grading.

6.4.1 Breed and gender effects

The increased lean meat yield of rams compared to wethers at similar ages or carcass weights has been well established (Butterfield et al. 1984; Arnold and Meyer 1988). The selected carcasses were typically Canadian in both conformation (3.0 ± 0.03) and GR (15.4 ± 0.09) (Stanford et al. 1995). Atypical lambs, either extremely lean or extremely lean and well-muscled, were not available during the time of the study. Purchas and Wilkin (1995) found lambs of excellent conformation (European E-class) to have increased saleable meat yield of the leg plus loin compared to non E-class lambs at the same GR and carcass weight. Accordingly, collection of additional data would be needed to determine the utility of VIAscan® in estimating the saleable meat yield of extremely lean and/or well-muscled lambs.

6.4.2 Principal component analysis

Principal component analysis identifies the potentially most useful variables among the large number recorded (in this case, 93) by selecting subsets of mutually independent variables that contain most of the original variation of the trait in question (Kramer 1978).

Principal component 1 explained 34% of the variation in saleable meat yield and can be considered a measure of overall frame size, since the selected variables were all positive and recorded some aspect of carcass dimensions. Principal component 2 explained 13% of the variation and was a measure of carcass muscling as the strongly weighted positive and negative variables recorded either the shape of the legs or colour variables, which could be indicative of muscling. Principal component 3 explained 9% of the variation and was a measure of gender due to marked changes in the variables included in this component when the data were sorted by gender. Principal component 4 explained 8% of the variation and was a measure of carcass fatness, having strong positive weightings of GR, carcass weight and colour variables that could be indicative of fat content and the strong negative weightings of lean and saleable meat yield. Other principal components had small R^2 values and were not further considered.

Separating the principal components by breed type did not alter any of the four main components, indicating that, within this data set, breed type was of minor importance in determining carcass characteristics.

6.4.3 Prediction of saleable yield and GR

The improved accuracy of VIAscan® in predicting saleable meat yield compared to GR is consistent with Australian results (Lissiman 1993) although the cutting lines for saleable yield and the VIAscan® parameters used in the predictions are not directly comparable due to different experimental protocols and conditions. In the Australian study, 44 Border Leicester x Merino lambs were cut-out, with predictions of saleable meat yield from VIAscan® (R^2 = 0.85, RSD = 1.20%) of higher accuracy than from GR (R^2 = 0.79, RSD = 1.45%). The usefulness of both colour and dimension variables as predictors of saleable meat yield in the present study is in contrast to the work of Horgan *et al.* (1995), where dimension variables were the only significant predictors due to variability in lighting.

As GR measurement influences carcass value under the present Canadian classification system, the ability of VIAscan® to predict GR was evaluated. Australian VIAscan® data (Lissiman 1993) on 1053 carcasses showed a similar accuracy of GR prediction to that of the present study (R^2 = 0.72, RSD = 1.8 mm). In the Australian work, GR readings were taken twice at the same site on the same carcass; one operator used a manual GR knife and another used an AUS-Meat probe, which allowed electronic capture of the GR measurement. These repeated measures of GR on the same carcass (R^2 = 0.75, RSD = 1.7 mm) were only slightly better than using VIAscan® to predict GR.

In conclusion, the accuracy of the VIAscan® for the prediction of saleable meat yield was better in the present study than in studies with beef (R^2 = 0.61, RSD = 1.5%, Jones et al. 1995) and compared favourably to the present Canadian Classification System for lamb (R^2 = 0.56, RSD = 1.3%, Jones et al. 1993). Accordingly, this VIA system shows great potential as a fully automated yet accurate method of lamb carcass classification.

6.5 References

Arnold, A. M. And Meyer, H. H. 1988. Effects of gender, time of castration, genotype and feeding regimen on lamb growth and carcass fatness. J. Anim. Sci. **66**: 2468-2475.

Butterfield, R. M., Zamora, J., Thompson, J. M. and Reddacliff, K. J. 1984. Changes in body composition relative to weight and maturity of Australian Dorset Horn rams and wethers. 1. Carcass muscle, fat and bone and body organs. Anim. Prod. **39**: 251-260.

Eldridge, G. A. and Ball, C. I. 1992. Variation in butt shape of British-cross and Brahman-cross cattle slaughtered for domestic consumption. Proc. Australian Soc. Anim. Prod. **19**: 61-64.

Gregor, G. and Scholz, A. 1993. Video image analysis in the determination of intramuscular fat content in pigs, and a discussion of breeding aims. Archiv-fur-Tierzucht **36**: 383-395.

Horgan, G. W., Murphy, S. V. and Simm, G. 1995. Automatic assessment of sheep carcasses by image analysis. Anim. Sci. **60**: 197-202.

Jones, S. D. M., Lang, D., Tong, A. K. W. and Robertson, W. 1992. A commercial evaluation of video image analysis in the grading of beef carcasses. Proceed. 38th Int. Cong. Meat Sci. Tech., August 23-28, Clermont-Ferrand, France, pp. 915-918.

Jones, S. D. M., Robertson, W. M. and Price, M. A. 1993. The assessment of saleable meat yield in lamb carcasses. Int. Cong. Meat Sci. Tech., Calgary, Alberta, p. 190 (Abstr.).

Jones S. D. M., Richmond, R. J. and Robertson, W. M. 1995. Instrument beef grading. Meat Focus Int. **4**: 59-62.

Karnuah, A. B., Moriya, K. Mitani, K. and Sasaki, Y. 1995. Estimation of beef carcass composition from the cross section around the longissimus muscle area in Holstein steers by computer image analysis. Animal Sci. Tech. **66**: 323-329.

Kramer, C. Y. 1978. An overview of multivariate analysis. J. Dairy Sci. **61**: 848-854.

Kuchida, K., Yamagishi, T., Takeda, H. and Yamaki, K. 1995. Live body volume and density measuring for estimation of carcass traits in Japanese Black steers by computer image analysis. Animal Sci. Tech. **66**: 1-6.

Lissiman, L. 1993. VIA sheep study, June 1993, New South Wales. Project M.334 for the Meat Research Corporation.

Patterson, D. L., Farid, A. and Smith, C. 1994. Video image analysis of carcass conformation of Texel cross and Cheviot lambs. Proceed. 5th World Cong. Genetics Applied to Livestock Prod. **19**: 485-488. Guelph, ON, 7-12 August.

Purchas, R. W. and Wilkin, G. H. 1995. Characteristics of lamb carcasses of contrasting subjective muscularity. Meat Sci. **41**: 357-368.

Richmond, R. J., Jones, S. D. M., Robertson, W. M. and Tong, A. K. W. 1995. Instrument beef grading (An evaluation of Video Image Analysis). Technical Report presented to the Canadian Meat Council, Marketing Services Branch.

SAS Institute, Inc. 1993. SAS User's Guide: Statistics. Version 6.10 ed. SAS Institute Inc., Cary, NC, 956 pp.

Scholz, A., Paulke, T. and Eger, H. 1995. Determination of marbling grade in pigs. Use of computer-assisted video image analysis. Fleischwirtschaft **75**: 320-322.

Stanford, K., Clark. I, and Jones, S. D. M. 1995. Use of ultrasound in prediction of carcass characteristics in lambs. Can. J. Anim. Sci. **75**: 185-189.

Webb, A. J. 1995. Future challenges in pig genetics. Anim. Breed. Abstr. **63**: 731-736.

Wood, J.D., Newman, P.B., Miles, C.A. and Fisher, A.V. 1991. Video image analysis: Comparisons with other novel techniques for carcass assessment. Proc. Symp. Elect. Eval. Meat in Support of Value-Based Marketing, March 27-28, Purdue Univ., IN., pp 145-169.

Table 6.1 Effects of sex and breed type on carcass weight, GR, average conformation score and saleable meat yield

	n	Carcass weight	Std dev[z]	GR	Std dev	Average conform	Std dev	Saleable yield (%)	SE
<u>Sex</u>									
Ram	9	24.3^{a}	2.7	8.5^{a}	4.5	3.1	0.3	80.3^{a}	2.4
Ewe	5	25.0^{ab}	2.7	16.3^{b}	4.2	3.2	0.4	77.9^{a}	2.5
Wether	44	27.2^{b}	3.3	17.2^{b}	5.3	3.2	0.7	76.4^{b}	3.3
<u>Breed</u>									
Suffolk-cross	16	26.7^{a}	2.8	15.3	4.4	3.2	0.4	78.0	2.4
Wool-breed	42	24.3^{b}	4.5	12.6	7.1	3.1	0.6	78.4	3.9

^{a,b} Between sexes, means within a column with different superscripts differ ($P < 0.001$) between breeds ($P < 0.05$).

^{z} Std dev, standard deviation

Table 6. 2 Principal components one through four, their associated variables and eigenvectors

Variable		Eigenvectors			
		Prin 1	Prin 2	Prin 3	Prin 4
Saleable meat yield (%)					-0.24
Carcass weight (kg)					0.21
GR					0.24
Carcass area		0.17			
Shape inside legs	(Var 1)[a]			0.17	
	(Var 2)		-0.14	0.21	
	(Var 3)			0.21	
	(Var 4)		-0.14		
	(Var 6-8)		0.11	-0.19	
Widths along the carcass	(Var 1-9)	0.16			
Areas along the carcass	(Var 1-6)	0.16			
	(Var 7-9)	0.11	-0.14	0.22	
Widths along the legs (Var 1-5)			0.13		
Areas along the legs			-0.16	0.24	
Widths at minima and maxima			0.14		
Body colour various patches				-0.14	0.12
Leg colour various patches (Var 1)			-0.14		
	(Var 2)			-0.13	
	(Var 4)			0.13	
Colour profiles at shoulder					-0.15
Colour profiles at loin (Var 1-2)				0.13	
Colour profiles at chump				0.15	0.15
Colour on shoulder, red					0.23
	green, blue		0.17		0.16
Colour on loin, red			0.14		0.21
	green, blue		0.22		
Colour on chump, red					0.21
	green, blue		0.17		
Colour on whole back, red				0.15	
	green, blue		0.24		
Carcass colour, red			0.18		0.21
	green, blue		0.18		
Widths across carcass (Var 1-8)		0.15			

[a] Var 1 is the first variable in a series of related variables.

Table 6.3 Equations for predicting carcass characteristics from video image analysis or lamb classification data

	Predicted variable					
			Primal cuts			
Regression Coefficients	Saleable meat yield (%)[z]	Saleable meat yield (%)[y]	Waste fat and bone(%)	Loin (%)	Leg (%)	Shoulder (%)
Intercept	72.94	79.21	13.04	20.35	20.72	35.71
GR		-0.42				
Conformation score		1.38				
Carcass weight	-0.62					
Shape inside of legs, Var 1[x]	-0.02			0.02		
Widths along carcass, Var 1	-0.06					
Widths along carcass, Var 2			0.08			
Widths along carcass, Var 3			-0.11	-0.01		
Width along legs, Var 1	0.11					
Width along legs, Var 4				0.05		
Colour profiles loin, Var 1			0.08			
Colour profiles loin, Var 2						-0.03
Colour on chump, green	0.03					
Widths across carcass, Var 5						-0.04
Widths across carcass, Var 7	-0.15					-0.03
Widths across carcass, Var 8	0.16					
Shape of inside legs, Var 3			-0.06			0.05
Area along legs, Var 2			-0.11			
Area along legs, Var 4				0.18		
Body colour patches, Var 2			0.21			-0.14
Body colour patches, Var 1				0.08		
Leg colour patches, Var 2				-0.11		
Widths at minima/maxima, Var 1						0.04
Curvature on back, Var 1						-0.08
R^2	0.71	0.52	0.62	0.71	NC[w]	0.62
RSD (%)	1.43	1.84	1.13	0.66	1.34	0.88

[z] Actual Saleable meat yield predicted by VIA data and carcass weight.

[y] Saleable meat yield predicted from GR and conformation score using equation of Jones *et al.* (1993).

[x] Var 1, variable 1 in a series of related variables

[w] NC, not calculated.

CHAPTER 7

General Discussion and Conclusions

7.1 General Discussion and Conclusions

Recent studies (Ward et al. 1995, Beermann et al. 1995) have shown that lamb has to change in composition (reduced fat, more lean) in order to be deemed acceptable by a majority of North American consumers. As carcass composition cannot be changed unless it can be predicted, all chapters of this thesis explored the *in vivo* and *ex vivo* prediction of lamb carcass composition in a Canadian context. Chapter 2 provided the backdrop of the current Canadian lamb supply chain and the role of carcass classification in the actual and preferred lamb-buying practices of Canadian abattoirs. Chapter 3 looked at the *in vivo* use of ultrasound as compared to the Canadian carcass classification system for prediction of saleable meat yield in lambs. Chapter 4 addressed the use of the *in vivo* ultrasound measurements of Chapter 3 in genetic programs for lamb carcass improvement. Chapter 5 compared a series of manual, objective measurements of lamb carcass dimensions to the subjective conformation scores currently in use for prediction of saleable meat yield in the Canadian Classification System. Chapter 6 carried the study reported in Chapter 5 another step further by comparing video image analysis (93 colour and dimension variables) with the Canadian Classification System for the prediction of saleable meat yield.

From this series of studies, a number of conclusions can be drawn, many with practical implications for the future classification of Canadian lamb carcasses. From Chapter 2, it became apparent that the majority of lambs in Canada are sold on a liveweight basis. Only 10% of an estimated 650,000 lambs slaughtered in Canada in 1996 had their carcasses classified according to Canadian standards, with the vast majority of these lambs slaughtered at one Alberta abattoir. Producer marketing groups and cooperatives evaluated another 5% of Canadian lambs based on carcass weight and subjective evaluations of fatness.

Due to the diversity of lamb marketing in Canada, four schemes would be necessary to effectively change the composition of Canadian lamb carcasses to meet consumer demand. The necessary schemes would be: (1) a method for predicting saleable meat yield *in vivo* with precision superior to traditional, subjective methods; (2) a method for incorporating *in vivo* prediction of saleable meat yield into a program for breeding stock selection; (3) an inexpensive, manual procedure for predicting saleable yield in carcasses, suitable for small abattoirs; (4) an automated method with a higher degree of precision than scheme (3), suitable for large abattoirs with rapid chain speeds.

From Chapter 3, ultrasound measurement of the maximum depth of subcutaneous fat taken *in vivo* was found to be of equal value to the Canadian carcass classification system for the prediction of saleable meat yield. The current Canadian carcass classification system is based on the equation of Jones et al. (1993) :

$$\text{Saleable yield \%} = 78.92 - 0.51GR + 1.25\ ASM,\ R^2=0.56,\ RSD=1.3\%$$

Where ASM is the average of three subjective muscling scores (for the regions of the leg, loin and shoulder) rounded to the nearest integer. The equivalent *in vivo* equation developed in Chapter 3 from ultrasound measurements is:

$$\text{Saleable yield\%} = 80.87 - 0.82SF,\ R^2=0.64,\ RSD=1.2\%$$

Where subcutaneous fat depth (SF) was measured at the first lumbar vertebra. The equation developed in Chapter 3 would be useful for live-grading lambs based on estimated saleable meat yield. However, the equation would not be useful in genetic programs for the selection of improved muscling in lambs.

The maximum depth of the longissimus muscle 'B' (Pálsson 1939) as measured by ultrasound has been recommended for inclusion with subcutaneous fat depth in selection indices to improve carcass composition in sheep (Gilmour et al. 1994; Olesen and Husabø 1994). The study described in Chapter 4 determined that ultrasound measurements of longissimus muscle dimensions and subcutaneous fat thickness should be adjusted by age of the lamb, provided that the measurements are made for a single contemporary/management group. This is in contrast to the work of other researchers (Gilmour et al. 1994; Hamlin et al. 1995) where adjustment of ultrasound measurements for variations in live weight was advocated for animals of wide-ranging ages from multiple farms/management groups. The study reported in Chapter 4 also determined that the cross-sectional area of the longissimus muscle as compared to live weight may be proportionally larger in ewe than in ram lambs. This finding may have little practical significance for genetic improvement programs, but may point to potential sex differences in chop size.

Chapter 5 addressed the value of subjective as compared to objective predictors of carcass composition. Subjective grading systems have a recognized difficulty maintaining standards over time, within and between graders (Kempster et al. 1976). As an alternative to subjective conformation scores, a number of measurements: carcass length (L), leg length (T), leg circumference (G), leg depth (H) were made on carcasses which were subsequently classified by trained graders according to Canadian standards. The following equation was developed:

Saleable meat yield% = 39.94 -0.21 GR +7.89G + 3.69(L/carcass weight), R^2=0.61, RSD=1.3

Although individual carcass measurements have been found to be poor predictors of carcass composition (Kempster 1981, Bennett et al. 1988), a number of measurements predicted saleable meat yield with precision equal to that of the Canadian Classification System. However, the objective measurements used in Chapter 5 would be too slow for commercial use. Consequently, the ease and speed of the current Canadian classification system would make it the scheme of choice for small abattoirs.

For large abattoirs with a throughput of at least 50,000 lambs per annum, the VIAscan® system discussed in Chapter 6 would offer objective, rapid, automated, cost-effective lamb grading. Using carcass weight and 93 video image analysis shape or colour variables taken from a dorsal view of the carcass, saleable meat yield% could be predicted with a R^2 of 0.71 and RSD of 1.43. Saleable meat yield was predicted by video image analysis approximately 20% more precisely than with the Canadian Classification System for lamb. Application of video image analysis for classification of lambs in Canada may be limited as there are only 3 abattoirs (one in Alberta and two in Ontario) with sufficient throughput to justify the capital expense of a video image analysis system.

In conclusion, this thesis offers four lamb carcass classification strategies designed to be of service to the Canadian sheep industry. Application of parts of this work are already underway with the recent implementation of a live lamb ultrasound grading program by the Ontario Sheep Marketing Agency and the incorporation of ultrasound measurements of subcutaneous fat depth and longissimus muscle dimensions into Ovissey®, the genetic improvement program of the Canadian Sheep Federation. In contrast, implementation of the classification schemes proposed in Chapters 5 and 6 is largely dependant on the whims of Canadian abattoirs. The concentration in the lamb slaughtering industry in Canada has created an oligopoly verging on a monopoly in some circumstances. The oligopoly in the lamb slaughtering industry has likely contributed to resistance for grading standards as highly concentrated industries have been shown to develop alternatives (not necessarily optimal) to both standards and grading (Bockstael 1987). The tools are in place for changing lamb carcass composition to better meet consumer demand. The ultimate survival of the Canadian sheep industry may depend on the implementation of these tools.

7.2 References

Beermann, D.H., Robinson, T.F. and Hogue, D.E. 1995. Impact of composition manipulation on lean lamb production in the United States. J. Anim. Sci **73**: 2493-2502.

Bennett, G.L., Meyer, H.H. and Kirton, A.H. 1988. Effect of average carcass fat concentration on correlations among lamb carcass measurements. Anim. Prod. **47**: 369-377.

Bockstael., N.E. 1987. Economic efficiency issues of grading and minimum quality standards In: *Economic Efficiency in Agricultural and Food Marketing*, R.L. Kilmer and W.J. Arbuster Eds. Iowa State University Press, Ames, pp 231-255.

Gilmour, A.R., Luff, A.F., Fogarty, N.M. and Banks, R. 1994. Genetic parameters for ultrasound fat depth and eye muscle measurements in live Poll Dorset sheep. Aust. J. Agric. Res. **45**: 1281-1291.

Hamlin, K.E., Green, R.D., Perkins. T.L., Cundiff, L.V. and Miller, M.F. 1995. Real-time ultrasonic measurement of fat thickness and Longissimus muscle area: I. Description of age and muscle weight effects. J. Anim. Sci. **73**: 1713-1724.

Jones, S.D.M., Robertson, W.M. and Price, M.A. 1993. The assessment of saleable meat yield in lamb carcasses. Int. Congr. Meat Sci. Technol. Calgary, AB, p. 190 (Abstr.).

Kempster, A.J., Avis, P.R.D., Cuthbertson, A. and Harrington, G. 1976. Prediction of the lean content of lamb carcasses of different breed types. J. Agric. Sci. **86**: 23-34.

Kempster, A.J. 1981. The indirect evaluation of sheep carcass composition in breeding scheme population studies and experiments. Livestock Prod. Sci. **8**: 263-271.

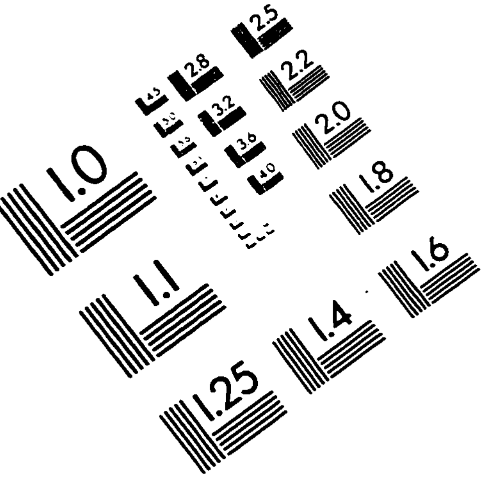
Nicoll, G.B., Alderton, M.J., Addandale, D.D., Colemen, I.D., Grimwood, , T.J. and Thomson, J.A. 1992. A terminal sire breeding programme based on screening for hogget live weight. Proc. N.Z. Soc. Anim. Prod. **42**: 125-127.

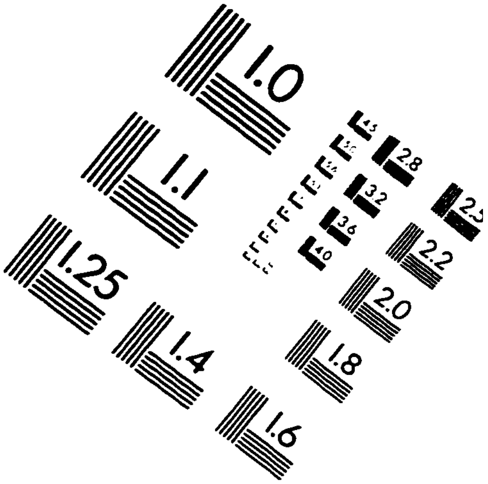
Olesen, I. and Husabø, J.O. 1994. Effect of using ultrasonic muscle depth and fat depth on the accuracy of predicted phenotypic and genetic values of carcass traits on live ram lambs. Acta Agric. Scand. Sect. A. **44**: 65-72.

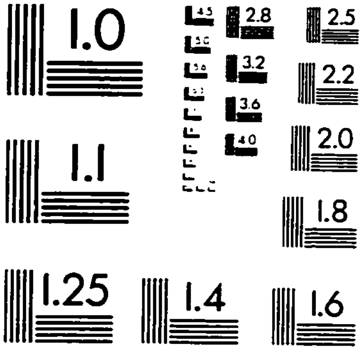
Pálsson, H. 1939. Meat qualities in the sheep with special reference to Scottish breeds and crosses. J. Agr. Sci. **29**:544-625.

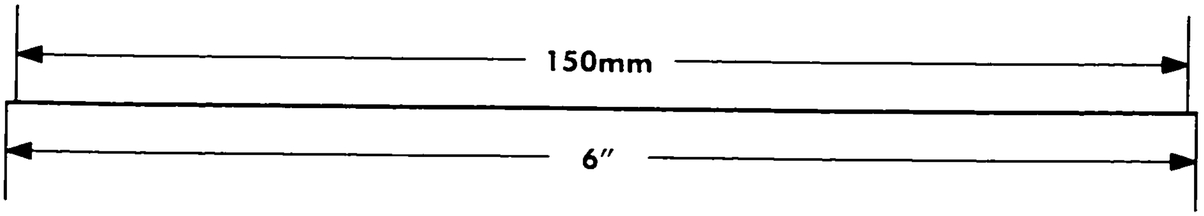
Ward, C.E. Trent, A., Hildebrand, J.L. 1995. Consumer perception of lamb compared with other meats. Sheep and Goat Res J. **11**:64-70.

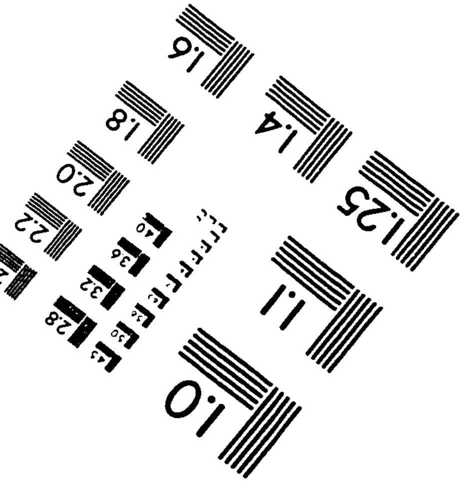
IMAGE EVALUATION TEST TARGET (QA-3)

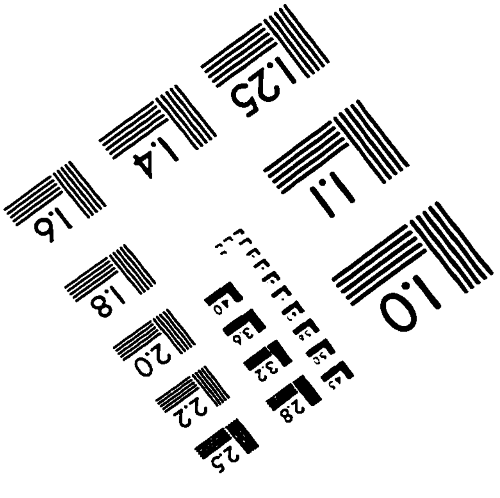












APPLIED IMAGE, Inc
1653 East Main Street
Rochester, NY 14609 USA
Phone: 716/482-0300
Fax: 716/288-5989