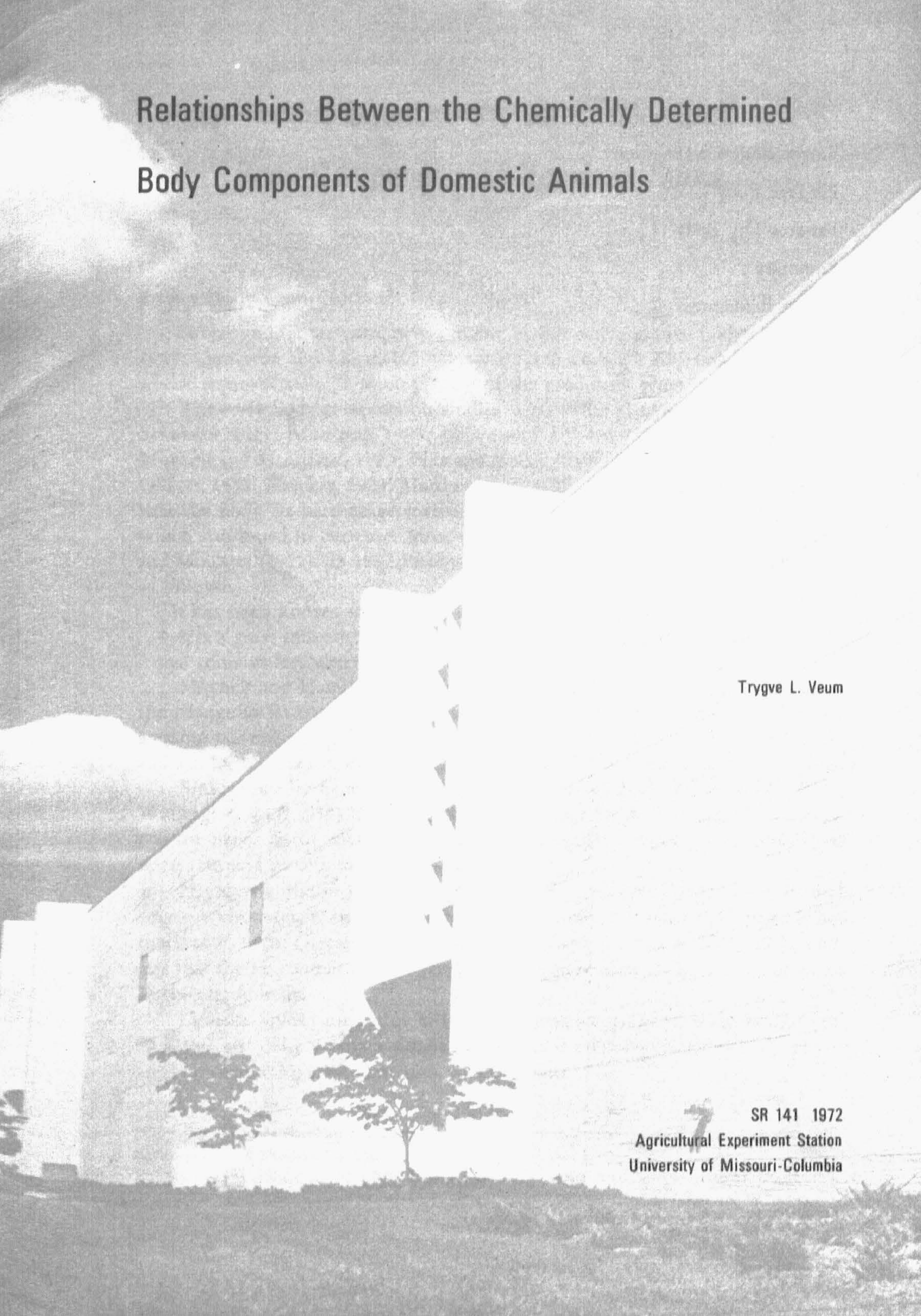
Relationships Between the Chemically Determined Body Components of Domestic Animals



Trygve L. Veum

SR 141 1972
Agricultural Experiment Station
University of Missouri-Columbia

CONTENTS

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Empty Body Composition[2]

Water and fat are extremely variable in the empty animal body (Reid *et al,* 1955; Crampton and Lloyd, 1959; Maynard and Loosli, 1962) and together constitute approximately 75 to 80 percent of the total body mass.

The early body composition studies with swine (Lawes and Gilbert, 1859; Swanson, 1921; Moulton, 1923; Ellis and Hankins, 1925; Hogan *et al,* 1925; Mitchell and Hamilton, 1929; Ellis and Zeller, 1934) and ruminants (Lawes and Gilbert, 1859; Haecker, 1920; Moulton *et al,* 1922, 1923,: Moulton, 1923) showed that the body fat percentage increased with age at the expense of body water which continued to decrease. Most of the early work was reviewed by Armsby and Moulton (1925). In 1887 Pfeiffer (cited from Moulton, 1923) quotes Hosslin as follows:

> "It has been known for a long time that the fat deposition in the tissues exerts a great influence on the water content of the same; the fattened animal contains less water, the richer it is in fat."

Mitchell and Hamilton (1929) stated that "the greatest change with age is the change in fat content." Increasing weight and age were associated with increasing percentages of fat and dry matter and decreasing percentages of protein and ash for all types of swine (chuffy, intermediate and rangy) they investigated.

Similar results have been obtained with growing cattle (Moulton, 1922; Wellington *et al,* 1954). Callow (1948) stated that the level of fat in the carcass was the major factor which influenced the chemically determined percentages of water, fat, and protein in the body tissues.

Highly significant correlations (-.97 to -.99) between empty body fat and empty body water in swine (Gnaedinger *et al,* 1963; Clawson *et al,* 1955; Babatunde *et al,* 1966; Gleeson, 1967) and the ruminant (Reid *et al,* 1955, 1963) indicate that the fat content may be predicted accurately from the percentage of water in the empty body.

Osinska (1962) used pigs killed over a narrow range of body weight (av. 90 kgm.) and did not obtain significant relationships between empty body weight and the chemical constituents of the empty body.

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[1]Contribution from the Missouri Agricultural Experiment Station. Journal Series Number 6279. Approved by the Station Director.

[2]Empty body is defined as the whole animal minus the contents within the gastrointestinal tract.

A review of the literature on the body composition of swine (Gleeson, 1967) illustrated that the percentages of fat and ash, followed by water, were more variable than protein in the empty body, which is in good agreement with the report on cattle (Reid *et al,* 1955). The empty body weight of swine (Gleeson, 1967) was highly correlated with the weights of the empty body components: water (0.997), fat (0.988), protein (0.996) and ash (0.979).

Empty body weight and age were highly correlated (0.87), which indicates that age accounts for only a small amount of the variation not already accounted for by empty body weight. The individual empty body components, with the exception of fat, were highly associated with age. Sex differences did not significantly affect the amount of water, protein or ash in the empty body (Gleeson, 1967), although barrows were significantly fatter than gilts at slaughter weights of 95 to 100 kgm.

The highly significant correlation and regression coefficients obtained between empty body weight and the weights of empty body components prompted Gleeson (1967) to propose a method for resolving the body composition of swine based on empty body weight alone or in combination with the modifying influences of age and sex, dependent on a known empty body water content.

Fat-Free Body

Moulton (1920) studied the fat-free flesh of beef cattle and found that the percentages of water (76 to 77%) and ash (1%) were not affected by age or degree of fatness, even though the percentages of protein and ash were influenced by under-nutrition. Callow (1947) reported that the concentration of water in the boneless fat-free body of beef cattle and sheep was remarkably close to 77 percent. This hypothesis was supported by work on guinea pigs (Pace and Rathbun, 1945) and rats (Babineau and Page, 1955), which suggested that water represented a constant proportion (72%) of the fat-free body mass, and that this constant was independent of the degree of body fatness.

Murray (1922) reported that the percentage of water in the fat-free body declined with increasing age for cattle, sheep, and swine. The ratio of protein to ash on a fat-free basis was relatively constant and was not affected by age, but could be influenced by nutrition. The ratio of protein to ash was higher and more variable for swine than ruminants. Murray (1922) concluded that the body composition could be resolved when live weight and fat content were known.

Since fat had been shown to be an extremely variable body component during growth and fattening, Moulton (1923) studied his data and several additional reports on the body composition of other mammalian species (mouse, rat, guinea pig, rabbit, cat, dog, swine, man, and cattle) on a fat-free basis in order to make more apparent the relationship between age or abnormal development and chemical composition. From these data Moulton (1923) introduced his concept of "chemical maturity," which he defined as "the point (age) at which the concentration of water, proteins, and salts become comparatively constant in the fat-free cell." These data supported an earlier report (Moulton *et al,* 1922) and showed that a rapid decrease in water concentration with a commensurate increase in protein and ash occurs in mammals from conception to birth, followed by less rapid but similar changes from birth up to an age where the percentages of water, protein, and ash in the fat-free tissue no longer show significant changes. The age at chemical maturity varied among the mammalian species studied, although the total life span expanded prior to the attainment of chemical maturity was similar (3.9 to 4.6%) for the species investigated. Therefore, Moulton (1923) concluded, as did Murray (1922), Mitchell and Hamilton (1929), Pace and Rathbun (1945), Babineau and Page (1955), and Callow (1947) that the composition of the fat-free body was not influenced by the relative fatness of the animal and the primary effect of fattening on the other body components (water, protein, and ash) was merely one of dilution.

However, the hypothesis that the fat-free mass is constant in composition (Murray, 1922; Moulton, 1923; Mitchell and Hamilton, 1929; Pace and Rathbun, 1945; Babineau and Page, 1955; Callow, 1947) has been challenged by subsequent work on swine (Spray and Widdowson, 1951; Clawson *et al,* 1955; Gnaedinger *et al,* 1963) including reviews on the body composition of swine (Gleeson, 1967) and cattle (Reid *et al,* 1955), in addition to studies on several small animals (Spray and Widdowson, 1951).

A study of the chemical composition of the mouse, rat, guinea pig, rabbit, cat, and pig (Spray and Widdowson, 1951) gave results which were in general agreement with Moulton (1923). Despite the fact that the various species were similar in their fat-free body compositions at maturity, the concentrations of a few specific elements (calcium, phosphorus, and magnesium) showed marked variation between species.

An investigation of the published data on the body composition of cattle (a range of 1 to 4,860 days of age) on a fat-free basis (Reid *et al,* 1955) resulted in the following mean percentages with their standard deviations: water, 72.9±2.0; protein, 21.6±1.5; and ash, 5.3±1.0. The work of Stroud (1961 verified these results. Even though these variations were small, highly significant correlations were obtained between age and the percentages of water (-.46), protein (0.44), and ash (0.43). Reid *et al.* (1955) stated the following:

> "Actual constancy of composition or true chemical maturity as conceived by Moulton (1923) is not reached during the first 4,000 days of life by the bovine. If chemical maturity is defined as the age at which the composition of the fat-free body becomes predictable or conforms closely to a mathematical generalization, then the bovine body is chemically mature at birth."

Gleeson (1967) found the chemical composition of the fat-free body of young and mature swine (means with standard deviations) contained more water (77.0±2.7%) and less protein (19.2±2.3%) and ash 3.9±0.8%) than the bovine (Reid *et al,* 1955). The fat-free body was not constant in composition (even at an empty body weight of 200 kgm. the fat-free body constituents continued to change, and chemical maturity had not been reached) and was influenced by empty body weight, age, and degree of body fatness. Sex had no effect on the fat-free body composition. Empty body weight and age were highly correlated (0.87) and had a significant effect on the percentages of water and protein which decreased and increased, respectively, with increasing weight and age.

The fat-free body constituents have been shown to be more closely related to weight than age in studies with swine (Mitchell and Hamilton, 1929; Murray, 1922; Hornicke, 1961; Gleeson, 1967) and ruminants (Murray, 1922; Taylor, 1964; Burton, 1967). Gleeson (1967) observed that the percentage of ash was affected by both empty body weight and age, which did not agree with the findings of Mitchell and Hamilton (1929) and Hornicke (1961), who found that the concentration of ash was independent of body weight in swine.

Highly significant correlations of -.58 and -.66 have been reported between the percentage of fat in the empty body and the concentration of water content in the fat-free body by Gnaediner *et al.* (1963) and Gleeson (1967). These studies substantiate the report by Clawson *et al.* (1955) indicating that the degree of body fatness influences the composition of the fat-free mass in swine. Gleeson suggests that the effect of empty body fat on the fat-free body water in these studies (Clawson *et al,* 1955; Gnaediner *et al,* 1963; Gleeson, 1967) may be directly related to body weight, since fat content increases with body mass.

Elsley *et al.* (1964) re-evaluated the carcass dissection of work of McMeekan (1940a, 1940b) adjusted to an equal fat-free body weight basis by linear regression. They found that the nutritional (energy) effects were mainfested mainly in fat deposition; and that the plane of nutrition did not affect the total weight of muscle or bone in relation to the total fat-free body weight

Fat-Free Dry Body

A reduction of the chemical composition from the fat-free to the fat-free dry basis reduces the coefficient of variation about the mean concentrations of protein and ash (Reid *et al,* 1963), resulting in greater accuracy in the prediction of body composition. The mean percentages of protein and ash (with standard deviations) in the fat-free dry body were reported to be relatively constant in cattle (80.3 ± 1.7 and 19.7 ± 1.7 respectively) by Reid *et al.* (1955) and in market weight swine (83.1 ± 1.6 and 16.9 ± 1.6 respectively) by Clawson *et al.* (1955). Age was found to be highly correlated with protein (-.42) and ash (0.42) in the fat-free dry bovine (Reid *et al.* 1955).

The fat-free dry body of swine, with a range in age of 1 to 923 days, was not constant in composition (Gleeson, 1967). Protein content was significantly correlated (0.22) with empty body weight but was not significantly affected by age or sex. Ash percentage was associated with both empty body weight and age, but not sex. The mean percentages of protein and ash (83.4 ± 5.4 and 17.0 ± 2.9, respectively) were similar to those reported by Clawson, although the standard deviations were considerably larger. Gleeson explains this discrepancy on the basis that the wide range of ages and weights included in his investigation added a source of variability which was not present in the study with market weight swine (killed at 97.5 kgm. live weight) by Clawson. The data of Murray (1922) and Hornicke (1961) are in good agreement with the reports on swine.

The results of these studies (Clawson *et al,* 1955; Reid *et al* 1955, 1963; Gleeson, 1967) indicate that species differ in their fat-free dry body composition, and the within-species variation which exists may be attributed, in part, to differences in age and weight.

Summary

A highly significant negative relationship exists in the empty animal body between fat and water. Increasing weight and age are associated with increasing percentages of fat and dry matter and decreasing percentages of protein and ash. Removal of the fat (fat-free body) improves upon the constancy of water, protein, and ash; which indicates that the primary effect of fattening on the other body components is one of dilution. A reduction in the chemical composition to the fat-free dry basis improves upon the constancy of protein and ash. Species differ in their fat-free dry body composition and the variation that exists within species may be attributed in part to weight and age.

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