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PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE CAMEL-BACK CONDITION IN LAMB CARCASSES AS INFLUENCED BY DIET

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An abnormal "camel-back" condition on Targhee sheep is defined as to: live back conformation score (camel-back); rate of gain, carcass value; muscle identity and size in the shoulder, back and loin; muscle pigmentation, and muscle protein, fat, water and selenium content. The effects of sire, rearing method, nutritional level and selenium injection on these characteristics are discussed. Data indicated that the "camel-back" condition was corrected by selenium injection and was correlated with fast early growth, longer and fatter carcasses, backbone abnormalities, bone composition alteration, less depth through the shoulder, back and loin, and specific changes in the development of selected muscles. Selenium injection, as influenced by rearing method, affected muscle pigmentation.

L'anomalie du "dos de chameau" chez le mouton targui se définit comme une excroissance dorsale vive (dos de chameau); taux de croissance, valeur de l'animal; identité et taille des muscles de l'épaule, du dos et des lombes; pigmentation et contenu en protéine, graisse, eau et sélénium des muscles. Discussion des effets de l'heredité, de la méthode d'élevage, du niveau de nutrition et d'injections de sélénium sur ces caractéristiques. Les résultats ont montré que le "dos de chameau" pouvait se corriger par des injections de sélénium et qu'il était en corrélation avec une croissance initiale rapide, avec la taille du sujet, les anomalies de l'épine dorsale, les altérations dans la composition des os, les mensurations à l'épaule, au dos et aux lombes, et avec des changements spécifiques dans le développement de muscles donnés. L'injection de sélénium, selon la méthode d'élevage, affecte la pigmentation des muscles.

Ein anormaler buckliger Zustand von Targhee Schafen ist von vielen Faktoren definiert: von dem Grad von Buckligkeit in lebendigen Schafen (bucklig); von der Zunahmegeschwindigkeit (Pfund pro Tag zugenommen); von dem Werteder Leiche; von dem Type und Grösse von Muskeln der Schulter, des Rückens und der Lende; von der Pigmentation des Muskels; von dem Eiweißstoff-, Fett-, Wasser- und Seleninhalt des Muskels. Die Wirkungen von Stammtier, Aufzuchtsmethode, Ernährungsstand und Seleninjektion auf diese Charakteristiken sind diskutiert. Die Tatsachen weisen darauf hin, dass der bucklige Zustand von der Seleninjektion korrigiert wurde und auf ein schnelles Frühwachsen, längere und dickere Leichen, Deformitäten des Rückgrats, Änderungen in der Zusammensetzung des Knochens, geringere Tiefe in der Schulter, dem Rücken und der Lende, und bestimmte Änderungen in der Entwicklung von ausgewählten Muskeln bezogen war. Die von der Aufzuchtsmethode beeinflusste Seleninjektion wirkte auf Muskelpigmentation.

Ненормальное состояние "верблюжьей спины(т.е. горба)" у овец породы Таргкхи определяется по отношению к следующим факторам: форма спины при жизни ("верблюжья спина"); ежедневная прибавка в весе; идентичность и размер мускулов в плече, спине и пояснице; пигментация мускулов и содержание в мускулах протеина, жира, воды и селена. В статье обсуждается, какое влияние имеют на эти свойства производитель, метод выращивания, уровень питания и инъекция селена. Данные показывают, что состояние "верблюжьей спины" исправлялось от инъекции селена и находилось в зависимости от быстрого раннего роста, от более длинных и жирных туш, от анормальностей в позвоночнике, от изменения состава костей, от меньшей толщины в плече, спине и пояснице и от специфических изменений в развитии некоторых мускулов. Инъекция селена, в зависимости от метода выращивания(т.е. один или два ягненка),влияла на пигментацию мускулов.

Introduction

An abnormal back conformation condition has been noted within the Targhee breed of sheep in the U.S.A. As early as 1961, some single born ram lambs of this breed developed an odd body shape immediately referred to as "camel-back". The North Central Regional Research (NCR) Report 198 (1970) characterized this condition in live lambs, reporting that "these lambs had high rough shoulders; a restricted heart girth; an exaggerated dip in back of the shoulders; a high arch to the backbone; an enlarged middle; and a characteristic high neck and a head carriage as though there was unusual tension in the Ligamentum nuchae, a heavy ligament at the back of the neck". It is reasonable to assume buyer rejection or discrimination for these lambs.

Examination of carcasses from three camel-back ram lambs by the Ohio Station indicated possible abnormalities of the spring of rib, vertebral arch, and tension in the Ligamentum nuchae (Horowitz and Plimpton, 1966). No detailed study of the anatomical definition of this "camel-back" condition has been reported, nor has it been established that these lambs represent an economic loss. The NCR Report (1970) does state that the worst "camel-back" lambs seem to be fast growing, single born lambs. This publication hints at a genetic cause as well as possible nutritional involvement, but admits that no work has been done to date on the cause or on a detailed definition of the "camel-back".

Parker, (1971) reported that in one study designed to examine the nature of the "camel-back" problem in coordination with a study to examine the relationship of white muscle disease to lamb pneumonia, researchers were disappointed to find no "camel-backs" to study. Subsequent examination of the design of that project revealed that all sheep had been injected with Barium Selenate as a part of the white muscle disease research, thus focusing attention on the possibility of selenium's involvement in the problem.

This current study was designed to: (1) define the "camel-back" condition in terms of carcass value, skeletal form, and muscle characteristics; (2) evaluate the role of growth rate (as created by rearing method and nutritional level) and (3) selenium injection on the incidence of the "camel-back" condition.

Procedure

Thirty-six ram lambs selected from Targhee ewes bred to four Targhee sires were randomly placed in two groups equalizing the single and multiple lamb rearing effect. The groups were designed to establish different growth rates through creep feeding versus pasture raising of the lambs. Lambs in Group I (creep fed) were confined with the ewes and were provided a pelletized creep feed, mixed with hay, water and trace mineralized salt. The pelleted feed contained: ground alfalfa hay, 29.5%; soybean oil meal, 9.8%; ground shelled corn, 59.0%; urea, 0.5%; trace mineral salt, 1.0%; vitamin A, D, and E supplement; and Aureomycin. The protein content of this ration was 12.75%. Group I lambs remained on this ration following weaning at 70 days of age.

Group II lambs (no creep feed) received mixed hay while confined, blue and orchard grass pasture once the season began, trace mineralized salt, and water, prior to weaning at 70 days of age. Following weaning these lambs were placed in feedlots and fed the same ration as Group I lambs.

To evaluate the effect of selenium on the "camel-back" condition, half of the lambs in each group received 1 cc. of BoSe (barium selenate and Vit E) at birth, 30, 60, and 90 days of age.

All lambs were weighed at birth, 30 days, weaning (70 days) and prior to shipment for slaughter at 55 kg. to determine growth rates during these periods. Lambs were subjectively scored as to "camel-back" conformation (1=none; 15=very severe).

Procedure and Discussion: Conformation and Skeletal Involvement

In Phase I a series of live, pre-rigor carcass and post-rigor carcass objective conformation measurements, involving skeletal dimensions, were obtained. The detailed procedures for these as well as their subsequent involvement in the "camel-back" problem were reported by Plimpton et al.(1973). These measurements included: body height measured at the third rib of the shoulder, at the tenth rib, at the center of the loin, and at the rump; and pre-rigor and post-rigor carcass depth, measured (in a hanging carcass) perpendicular to a reference line (running from the anterior end of the stifle joint to the anterior position of the joint between the humerus and scapula) at the same points on the back as used for the live measurements. In addition measurements were reported as to: the width of the 9th-13th thoracic vertebrae bodies; the distance between ribs 9-13; the spring of the rib cage measured perpendicular to the rib cage at the midpoint of a line dropped from the 10th thoracic vertebra to the xiphoid process of the sternum; carcass length from the first rib where it articulates with the vertebra to the anterior end of the aitch bone; the height of the vertebral arch measured to the ventral surface of the column at each of the previously mentioned back points from the aforementioned reference line; and the maximum height of this arch.

A selected summary from the above mentioned measurements reported by Plimpton et al. (1973) is included in Table 1. Fast growth rate from birth to weaning was significantly ($p<.05$) related to increasing severity of the "camel-back" condition.

TABLE 1. SIMPLE CORRELATIONS: "CAMEL-BACK" CONFORMATION AND AVERAGE DAILY GAIN (ADG) VERSUS SELECTED CARCASS MEASUREMENTS

	"Camel-Back" Conformation Score	Avg. Daily Gain (ADG) by Period		
		Total	Birth to Weaning	Weaning to Slaughter
ADG, total	0.33*	--	--	--
ADG, birth to weaning	0.33*	0.96**	--	--
ADG, weaning to slaughter	-0.08	-0.08	-0.66**	--
Pre-rigor back depth, 10th rib	-0.48**	-0.60**	-0.55**	0.44**
Space between the ribs, 9-10th rib	-0.34*	0.19	0.18	-0.19
Chine width, 10th thoracic vertebra	0.36*	0.47**	0.45**	-0.31
Ligamentum nuchae elasticity	-0.02	0.46**	0.44**	-0.32*
Carcass quality grade	0.35*	0.40*	0.42**	-0.38*
Fat thickness, 12-13th rib	0.34*	-0.01	-0.08	0.13
Trimmed leg %	-0.54**	-0.38*	-0.42**	0.26

* Significant ($P<.05$)
** Significant ($P<.01$)

A definite skeletal malformation was reported associated with the "camel-back" condition. Pre-rigor body depth measurements at all four points were negatively correlated ($p<.01$) with the "camel-back" score and the magnitude of the negative correlation increased from shoulder to rump. The same measurements obtained post-rigor were significant and negatively correlated at the shoulder

and 10th rib only. The need to evaluate muscular systems in this situation is obvious. The determination of the height of the ventral surface of the vertebral bodies from the reference line provided a measure of backbone contour. Significant ($p<.05$) negative correlations of r=-0.36, -0.42 and -0.32 between the measurement at the 3rd rib, 10th rib and center loin, respectively and "camel-back" score demonstrates the lack of arch.

This lack of arch could also explain the positive (r=0.47) correlation between carcass length and "camel-back" score.

The most visible and identifiable skeletal feature associated with the "camel-back" condition was an enlargement of the vertebrae bodies (chine bones) from the 9th through 11th ribs. Positive and significant ($p<.05$) correlations ranging from 0.36 to 0.40 were reported for chine bone width and "camel-back" score. The vertebral column at this point bulged laterally and ventrally, resulting in the ribs being spaced more closely where they articulate with the vertebra. Correlation between width of the chine bone of the 10th thoracic vertebra and the vertebral arch was 0.38.

Plimpton et al. (1973) also reported on detailed carcass value data, ranging from carcass yield and quality grades and percent of untrimmed and trimmed wholesale cuts to edible portion studies of the leg. As summarized in Table 1, "camel-back" carcasses were characterized by higher quality grades, greater fat thickness and a loweryield of trimmed cuts. Thus the industry must give more than academic notice to the "camel-back" condition.

Although the "camel-back" condition has been defined through a number of variations in normal skeletal form the mineral analysis of the bone did not indicate any significant composition involvement in the problem.

Plimpton et al. (1973) did examine the relationship between the "camel-back" condition and the elasticity of the Ligamentum nuchae, as well as its elastin and collagen content. Early rapid growth did result in greater elasticity (extension per gm. of ligament), but this effect was not conclusively confirmed by the elastin and collagen content. No significant relationship between backbone abnormalities and Ligamentum nuchae elasticity was reported.

Procedure and Discussion: Muscle Anatomy and Composition

At the time of the carcass wholesale cut (untrimmed and trimmed) yield determinations, muscle areas were calculated from cross sectional muscle tracings obtained from slices made at seven points along the back, cut perpendicular to the long axis of the carcass. The seven sections were: first rib; third rib; fifth rib; ninth rib; twelfth rib; fourth lumbar vertebra (center loin); crest of the ilium. All muscles were identified using Kauffman et al. 1963 as a reference and all muscle areas were calculated to determine the muscle area relationships to the "camel-back" condition and to growth rate.

A section of the Longissimus thoracis from the 10th-13th rib was obtained and used for the subsequent evaluation of pigmentation, selenium content and proximate composition. Total pigmentation and myoglobin content were determined using the procedure of Richansrud and Hendrickson, 1967. Selenium muscle content was determined using the procedure of Olson, 1969 and proximate composition was obtained according to the method of the A.O.A.C., 1965.

Statistical evaluation included simple correlations without treatment effects being removed and the least squares analysis of variance was according to the procedure of Harvey, 1960. The analysis included sire, method of rearing (single or multiple births), nutrition group (creep or no creep), selenium and the two-way interactions.

Table 2 presents selected correlations involving those muscle areas apparently related directly to the "camel-back" condition or indirectly through growth rate. In all, cross sectional areas were determined for: twelve muscles at the first rib; eleven muscles at the third rib; six muscles at the fifth rib; five muscles at the ninth rib; two muscles at the twelfth rib; four muscles at the fourth lumbar vertebra; and five muscles at the ilium. From these, only the muscles listed in Table 2 seemed even remotely related to the problem.

TABLE 2. SELECTED CORRELATIONS: MUSCLE AREAS AND COMPOSITION VERSUS "CAMEL-BACK" CONFORMATION SCORE AND GROWTH RATE

	"Camel-Back" Conformation Score[1]	Average Daily Gain (ADG) by Period		
		Total	Birth to Weaning	Weaning to Slaughter
MUSCLE AREAS				
Supraspinatus, 1st rib	0.29	0.34*	0.21	0.05
Infraspinatus, 1st rib	-0.10	-0.36*	-0.34*	0.14
Trapezius thoracis, 3rd rib	-0.32*	-0.62**	-0.54**	0.40*
Subscapularis, 3rd rib	-0.35*	-0.15	-0.21	0.31
Serratus ventralis thoracis, 3rd rib	0.22	0.37*	0.31	-0.34*
Longissimus thoracis, 3rd rib	0.08	-0.47**	-0.48**	0.45**
Spinalis thoracis, 9th rib	-0.02	0.29	0.34*	-0.52**
Latissimus dorsi, 9th rib	0.11	0.29	0.16	0.20
Psoas major and minor, ilium	-0.35*	-0.22	-0.31	0.45**
Longissimus Thoracis Composition				
Pigmentation, total	-0.23	-0.05	-0.03	0.08
Myoglobin	0.00	-0.02	-0.10	0.21
Selenium, dry basis	0.10	0.49**	0.50**	-0.20
Fat, %	0.14	0.02	0.17	-0.26

* Significant, $P<.05$
** Significant, $P<.01$
1 = none; 15 = severe

The "camel-back" condition was associated in the shoulder area with decreased area of the Trapezius thoracis and Subscapularis, measured at the third rib. Rapid early growth, a characteristic of the "camel-back" lamb, was also related to decreased Infraspinatus area at the first rib. All of these muscles are associated with position or movement of the scapula. The Infraspinatus holds the scapula and humerus together laterally, while the Subscapularis holds them together medially. The Trapezius thoracis raises the scapula, advancing and retracting it, since this muscle runs from the dorsal midline to the spine of the scapula. These relationships may help explain the high rough shoulder of the "camel-back" as described in the NCR Report (1970). Apparent, but less significant increases in the Supraspinatus, which extends the shoulder, and the Serratus ventralis thoracis which slings the body between the forelimbs, would support this observation. Increased area in these two muscles would tend to broaden the shoulder.

From the standpoint of carcass value, apparent reduction in Longissimus thoracis area associated with rapid early growth and reduction in size of Psoas major and minor are of interest.

It is not apparent at this time whether muscle growth or its failure to grow at the same pace as the thoracic vertebrae could be involved in the skeletal malformations previously discussed. Of the muscles of the back or vertebral column only the significant decrease in Longissimus thoracis area and the significant increase in Spinalis thoracis area are correlated with rapid early growth. Both muscles are said to erect or extend the vertebral column. One could argue that greater tension of the Spinalis thoracis could cause the dorsal processes of the thoracic vertebrae to be pulled together permitting the backbone condition previously described, and failure of the Longissimus thoracis to develop would give no opportunity to counter this effect. More study of these muscles is required during the growth of the lamb.

Muscle composition did not appear to be influenced by the "camel-back" condition nor growth rate, with the exception of muscle selenium content, which on a wet and dry basis was significantly ($p<.01$) greater in the lambs which gained most rapidly from birth to weaning and thus, in the entire experiment. This storage of selenium in the muscle of lambs potentially "camel-back", might

represent a failure of the lamb to use the selenium. Selenium injections significantly ($p < .05$) reduced the incidence of the "camel-back".

Results: Treatment Effects on the "camel-back" Characteristics

Data concerning sire effect are inconclusive because of insufficient lamb numbers with certain sires. However, two of the sires produced lambs with higher "camel-back" scores and these yielded carcasses characterized by less body depth, less space between the ribs, greater spring of rib, greater width from the 9th to 12th thoracic vertebrae and a lower yield of percent of trimmed leg.

TABLE 3. LEAST SQUARES MEANS FOR SELENIUM, NUTRITION LEVEL AND REARING EFFECT ON THE "CAMEL-BACK" CONDITION, GROWTH RATE AND SELECTED MUSCLE CHARACTERISTICS

	Selenium		Nutrition		Rearing-Birth	
	BoSe	None	Group I (creep)	Group II (no creep)	Single	Multiple
Conformation Score	4.93	6.41**	6.36	5.10	5.83	5.63
Average Daily Gain (Birth to Weaning), kg. per day	0.29	0.29	0.33	0.24**	0.33	0.24**
Average Daily Gain (Total), kg. per day	0.26	0.27	0.30	0.24**	0.29	0.24**
Long. thoracis composition						
Pigmentation, mg/g	3.17	3.00	3.14	3.03	3.10	3.07
Selenium, ppm (dry basis)	0.169	0.154	0.154	0.162	0.177	0.138
Ether extract %	9.10	7.10	8.8	7.3	8.3	7.8
Muscle Areas						
Supraspinatus (1st rib), $cm.^2$	5.16	9.35**	6.97	7.55	8.84	5.74*
Infraspinatus (1st rib), $cm.^2$	14.97	14.06	14.58	14.45	13.61	15.48
Trapezius thoracis (3rd rib), $cm.^2$	4.39	4.97	3.10	6.32*	3.94	5.48
Subscapularis (3rd rib), $cm.^2$	6.26	5.55	5.94	5.87	5.61	6.26
Serratus ventralis thoracis (3rd rib), $cm.^2$	14.65	15.03	16.58	13.10	15.61	14.06
Longissimus thoracis (3rd rib), $cm.^2$	0.65	0.58	0.65	0.65	0.71	0.65
Spinalis thoracis (9th rib), $cm.^2$	2.77	3.61	3.23	3.16	4.00	2.45
Latissimus dorsi (9th rib), $cm.^2$	2.39	3.74**	2.84	3.29	3.61	3.52*
Psoas major and minor, (ilium), $cm.^2$	6.39	6.65	6.00	7.10	6.39	6.65

* Significant ($p < .05$)
** Significant ($p < .01$)

Means for selected traits shown to be involved in the "camel-back" condition are presented in Table 3. BoSe (Selenium plus Vit. E) injections significantly reduced the incidence of the "camel-back" condition. Selenium treatment also affected those conformation and skeletal measures which were previously shown (Table 1) to be involved in the definition of the "camel-back". These selenium injected lambs had greater back depth, greater spacing between the ribs, greater yield of trimmed leg and less chine bone width at the 9-12 thoracic vertebrae. Although the "camel-back" lambs were characterized by rapid growth from birth to weaning, selenium did not have its effect by altering growth rate.

The effect of selenium on muscle areas is basically consistent with the previously discussed muscle involvement in the "camel-back" condition. However, the only selenium muscle effects which were significant were the reduction in area of Supraspinatus and in the area of the Latissimus dorsi. Selenium injections resulted in a slight improvement in muscle pigmentation and in an increase in muscle selenium levels. The non-significant increase in ether extract percentage is consistent with the fact that selenium treated lamb carcasses also had more external fat.

It is of significance to note that significant interactions involving muscle areas of Infraspinatus and the Latissimus dorsi and muscle pigmentation indicate that the single lambs were most affected by selenium injection and in fact reverse effects were noted for the multiple birth lambs.

As expected, creep feeding of the lambs in Group I resulted in significant increases in growth rate from birth to weaning and a subsequent increase in the "camel-back" score. The increase in muscle pigmentation and ether extract content are expected for the higher plane of nutrition. Selenium content in the muscle of lambs raised as twins or triplets was significantly improved by creep feeding. No apparent increase was noted for single lambs.

The significant decrease in area of Trapezius thoracis is consistent with its "camel-back" muscle involvement as presented in Table 2.

Although the NCR (1970) Report suggested that the "camel-back" condition was most prevalent in single born lambs, these differences were not significant. The single born lambs did gain more rapidly, were fatter, and had a higher level of muscle selenium but this would be as expected because of greater nutrient availability during and after gestation.

The significantly greater Supraspinatus and Latissimus dorsi muscle areas of the single born lambs are consistent with the increases in the muscle areas associated with the "camel-back" condition. Smaller areas of the Infraspinatus, Trapezius thoracis, Subscapularis and Psoas major and minor muscles also support the more prevalent "camel-back" problems in single born lambs.

In conclusion, it does appear that the "camel-back" condition defined in this paper in rapid gaining, single born lambs from particular sires was improved by repeated injection with BoSe (Selenium plus Vit. E).

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