EFFECT OF SOUND STRESS ON BEEF CARCASS QUALITY

by

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INTRODUCTION

Increased population density and technological advances have added much noise to our environment, particularly in urban areas. Environmental noise has become serious enough to be considered a form of pollution. The American Speech and Hearing Association and Public Health Service considered noise pollution significantly important in 1968 to jointly sponsor a Conference on Noise as a Public Health Hazard for discussion of effects and control of noise. The effect of noise on humans and laboratory animals has been investigated but little is known about the response of meat animals to sound stress.

Pre-slaughter treatment of beef cattle may strongly influence their physiological state. Cattle encounter a variety of environmental stresses as they move directly or through central markets to slaughter plants. Excessive noise and excitement compound the stress effects and induce physiological responses which may result in dark colored postmortem muscle tissue.

Beef muscle color is a major factor in determining saleability of retail cuts. Dark colored retail cuts are generally considered deteriorated and are passed over in the meat showcase. Beef carcasses containing muscle that fails to brighten upon exposure to air, known as "dark cutters", must be discounted because of consumer reluctance to select dark colored retail cuts. Price discounts represent considerable economic loss to meat packers with a high incidence of dark cutters.

This study was conducted to determine if exposure of beef slaughter cattle to high intensity noise for 12 to 24 hours antemortem would result in dark cutting carcasses.

Chapter II

REVIEW OF LITERATURE

Definition of Sound Terminology

Sound travels as a wave in an elastic medium. The wave may be in a plane or spherical shape depending on size of the source and distance from the source (Ward and Fricke, 1968). Sound waves originating from a point source have a spherical shape when close to the source but a specified segment of the wave gradually becomes flatter or more like a plane as it travels farther from the source. Sound waves emitted from a large source are considered to be plane waves. A sound wave is propagated in air as a series of compressions and rarefactions. The compressions cause slight increases in barometric pressure while the rarefactions result in small decreases in barometric pressure. It is the change in pressure that produces vibrations of the ear drum and consequent hearing. Pressure is force per unit area and sound pressure is measured in units of dynes per square centimeter (Gulick, 1971). An abbreviated system of measuring sound pressure levels uses decibels (dB) which is a logarithmic function:

$$N(dB) = 20 \log \frac{P_1}{P_2}$$

N = number of decibels
P_1 = pressure to be compared to the reference pressure
P_2 = reference pressure, widely accepted as 0.0002 dyne/cm^2

Table 1 shows the sound pressure levels (dB) of a few common sounds (Beranek, 1966).

TABLE 1. SOUND PRESSURE LEVELS OF SOME COMMON SOUNDS

Source	dB Level
Zero loudness	0
Whisper	30
Quiet office	40
Home	45
Conversation	60
Automobile	70
Noisy office	75
Street	80
Airplane	105
Rocket	115
Thunderclap	120

Frequency refers to the vibrations of the sound source per unit time and is measured in hertz (Hz) or cycles per second (cps) (Gulick, 1971).

TABLE 2. FREQUENCIES EMITTED AND RECEIVED BY VARIOUS ANIMALS

Animal	Emissions (cps)	Reception (cps)
Man	85 to 1,100	20 to 20,000
Dog	452 to 1,080	15 to 50,000
Cat	760 to 1,520	60 to 65,000
Green Frog	50 to 8,000	50 to 10,000
Robin	2,000 to 13,000	250 to 21,000
Grasshopper	7,000 to 100,000	100 to 15,000

Table 2 shows the frequency ranges in which sounds are emitted and received by various animals as reported by Stevens and Warshofsky (1965).

Physiological Responses of Laboratory Animals to Sound Stress

Several researchers have investigated effects of intense sound on different laboratory animals with most studying physiological responses to sound stress and a few observing behavioral changes. Change in weight of adrenal glands has been used in measuring the physiological effect of sound stress (Anthony and Ackerman, 1955 and Sackler *et al.*, 1959).

Anthony, Ackerman and Lloyd (1959) subjected rats, mice and guinea pigs daily to high intensity noise in a frequency range of 150 to 4800 cps at a sound pressure level of 140 dB. Organ weights (adrenals, thymus, spleen, testes, prostates and seminal vesicles) in rats and guinea pigs showed no consistent differences indicating varied endocrine responses. Mice exposed to the noise had heavier adrenals than the control litter mates.

Adrenal hypertrophy was reported by Ingle (1952), Hale (1952), Anthony (1956) and Sackler et al. (1959) when laboratory animals were exposed to high intensity sound. Histochemical analysis revealed adrenal gland hypertrophy due to enlargement of cortical cells and widening of the fasciculate zone of the adrenal cortex (Anthony and Ackerman, 1955 and Anthony, 1956).

No permanent change in the size or weight of adrenal glands of rats and mice exposed to intense noise was found by Anthony and Ackerman (1955), Anthony and Babcock (1958) or Samorajski, Rolsten and Ordy (1971). Rosecrans, Watzman and Buckley (1966) suggested the absence of hypertrophy after eight weeks of stress indicated the adrenals became more efficient in producing corticosteroids.

Changes in body weight of stressed laboratory animals were noted by Sackler et al. (1959) and Takahashi et al. (1969) with sound stressed female mice showing reduced weight gains. Takahashi et al. (1969) reported that sound stressed male mice gains were not different from the controls.

McCann et al. (1948) reported increased blood pressure in rats exposed to auditory stimulation. A frequency of 20,000 Hz at a sound pressure level of 160 to 165 dB caused death in mice within one minute of exposure (Allen, Frings and Rudnick, 1948). Anthony and Babcock

(1958) monitored serum electrolyte concentration in sound stressed mice but found no significant difference from controls. Exposure to a sound level of 120 dB for 10 minutes was the threshold for cell damage to the organ of Corti in guinea pigs (Nakahara, 1970). Reduced fetal weight, complete or partial resorption of fetuses, cranial hematoma, dwarfed hind limbs and tail defects resulted from audiogenic stress of pregnant albino mice (Ward, Barletta and Kaye, 1970).

High intensity sound has been shown capable of inducing extreme stress in rats, mice and guinea pigs. Responses to stress vary according to treatment and within and between species but all indicate involvement of the endocrine system.

Physiological Responses of Farm Animals to Stress

Arehart (1970) observed changes in heart and respiration rates of lambs subjected to three types of sounds; USASI (United States of America Standard Institute) noise, instrumental music, and IMS (Intermittent Miscellaneous Sounds) noise. Two intensity levels were used, 75 dB and 100 dB. When exposed to USASI noise, lambs not acclimatized to the noise had significantly higher ($P<.01$) heart rates. Respiration rates of both acclimatized and non-acclimatized lambs were significantly higher at 100 dB. Non-acclimatized lambs exposed to 75 dB of instrumental music responded with higher respiration rates than either the acclimatized or non-acclimatized groups subjected to 100 dB. However, over a 12-day period, 100 dB sound intensity caused significantly higher ($P<.05$) heart rates in both acclimatized and non-acclimatized lambs. Non-acclimated lambs showed higher respiration rate at 75 dB of IMS noise and higher heart rate at 100 dB.

Swine exposed to aircraft noise up to 120 dB responded with significantly higher heart rates (Bond and Winchester, 1963).

Stress-resistant pigs adjusted to a warm environment (42^{o}C) and maintained a homeostatic condition more readily than did stress-susceptible pigs according to Forrest et al. (1968). Unanesthetized stress-resistant pigs showed an increased heart and respiration rate of 25 and 400 percent, respectively, while stress-susceptible pigs showed increases of 200 and 300 percent, respectively. When anesthetized, heart and respiration rates in the stress-resistant pigs showed no change while the stress-susceptible group showed an 18 percent rise in heart rate and a slight rise in respiration rate. Results from this study agreed with those of Judge et al. (1968b) who suggested that heart and respiration rates of stress-susceptible pigs were under adrenal hormone influence to a lesser degree than in the stress-resistant pigs. The former researchers (Forrest et al., 1968) speculated that the differences in responses were due to adrenal insufficiency in the stress-susceptible group. In an earlier investigation reported by Ludvigsen (1957), pigs suffering from what he called "muscle degeneration" disease were described as having a less functional adrenal cortex than normal pigs.

Kastenschmidt et al. (1965) reported no significant differences in adrenal gland weights between treatment groups when pigs were exposed to different thermal conditions. However, they noted that pigs showing rapid postmortem glycolysis had lighter adrenal weights. Lambs stressed with periodic electrical shocks showed some hypertrophy of adrenal glands (Judge and Stob, 1963). Judge et al. (1968a) speculated that adrenal gland weight was related to the functional status of the gland.

As reported by Funkenstein (1955), animals respond to stress in different ways but the function of the adrenal gland is associated with each response. Such responses may be partially characterized by changes in heart and respiration rates and increased adrenal activity.

Stress and its Effects on Muscle Quality of Farm Animals

A variety of methods have been employed as "stressors" to study the influence of environmental stress on meat animal muscle quality. Epinephrine or adrenaline has been injected into lambs (Hedrick *et al.*, 1961; Judge and Stob, 1963 and Forrest, Merkel and Mackintosh, 1964), pigs (Anglemier *et al.*, 1961 and Hedrick, Parrish and Bailey, 1964) and cattle (Hedrick, Brady and Turner, 1957). Pigs (Lewis, Heck and Brown, 1961 and Hallund and Bendall, 1965), cattle (Lewis, Brown and Heck, 1965) and lambs (Judge and Stob, 1963) have been electrically stimulated. Pigs (Briskey *et al.*, 1959a,b) and lambs (Forrest *et al.*, 1961, 1964) were exercised to near exhaustion and pigs were subjected to abrupt changes in environmental temperature (Sayre *et al.*, 1961 and Kastenschmidt, Briskey and Hoekstra, 1964). Muscle characteristics such as color, pH, glycogen and lactic acid content, water-holding capacity, tenderness and firmness were studied.

Hedrick *et al.* (1961) reported a darkening of lamb flank muscles as "adrenaline" dosage increased and Forrest *et al.* (1961) found significant increases in muscle myoglobin concentrations. Pork muscle was also found to be darker colored after pigs were stressed by "adrenaline" injection (Hedrick *et al.*, 1964). Dark-cutting beef was caused by injecting 3 mg of "adrenaline"/100 lbs. of body weight 24 hours antemortem (Hedrick *et al.*, 1957). Postmortem muscle pH increased from a 5.5 to 5.7 range in nonstressed cattle to a range of 6.0 to 6.2 in cattle treated with "adrenaline" 24 hours preslaughter (Hedrick et al., 1957). The researchers specified that stress should last at least 24 hours to cause the dark cutting condition. "Adrenaline" treatment also increased ultimate pH values in lambs (Forrest et al., 1961, 1964 and Judge, 1969) and pigs (Anglemier et al., 1961 and Hedrick et al., 1964) while lactic acid levels in pork were inversely related to postmortem muscle pH (Anglemier et al., 1961). Hedrick et al. (1961) observed that lamb flank muscle became darker and the amount of myoglobin extracted decreased significantly ($P<.01$) as pH increased. No significant relationship was found between flank color score and myoglobin content. Contrary to these results Judge and Stob (1963) found no significant difference in muscle color of lambs when epinephrine was injected daily for 93 days at a rate of 10mg/100 lbs. of body weight, but did find a higher ultimate muscle pH.

Preslaughter "adrenaline" treatment had no effect on water-holding capacity of ovine muscle according to Forrest et al. (1961). However, Forrest et al. (1964) in a similar study observed a slight increase in water-holding capacity.

Anglemier et al. (1961) reported that flavor panel results indicated loin samples were significantly more tender from epinephrine stressed pigs, but no tenderness differences were noted in lamb muscle after stress (Forrest et al., 1964).

Electrical stimulation (electric prods) has been used to study the influence of stress on various muscle characteristics. Judge and Stob (1963) observed no treatment effect on lamb muscle color but muscle was darkened by electrical shock treatment in pigs and cattle in work reported by Hedrick *et al.* (1959) and Lewis *et al.* (1961a,b, 1962c, 1965).

Hedrick *et al.* (1959) reported postmortem pH increased from 5.4 in two control cattle to 6.4 and 6.7 in cattle stressed electrically. Electrical shock on pigs resulted in higher pH values and lower lactic acid levels than normal (Lewis *et al.*, 1962b). These workers found lactic acid levels significantly lower ($P<.05$) in *psoas major* and *quadriceps femoris* muscles. Comparison of *psoas major* pH values in stressed and nonstressed pigs (6.3 and 5.8, respectively) revealed significant ($P<.01$) differences at 24 hours and at 48 hours ($P<.05$) (6.3 and 6.0, respectively). Similar pH values were reported for the *quadriceps femoris* muscle. Lewis *et al.* (1961b, 1962a) reported a significant ($P<.01$) increase in pH of the *psoas major*, *quadriceps femoris* and *longissimus* muscles from pigs stressed with electrical shocks. Hallund and Bendall (1965) stressed Danish Landrace pigs with electricity and concluded that the treatment accelerated the rate of pH fall with subsequent muscle tissue being pale, soft and watery.

Lactic acid concentration and pH 14 days postmortem in *psoas major*, *quadriceps femoris* and *longissimus* muscles from electrically stressed steers were found to be closely related with correlations of -.78, -.73 and -.43, respectively (Lewis *et al.*, 1962c). This pointed out that final pH is largely determined by the degree of production of lactic acid postmortem. An increase in postmortem pH resulted from electrical shock treatment in other studies with steers (Lewis *et al.*, 1963, 1965) and with lambs (Judge and Stob, 1963).

Lewis *et al.* (1962a) reported significant increases in tenderness of fresh ham ($P<.05$), *psoas major* ($P<.01$) and *quadriceps femoris* ($P<.05$)

muscles after pigs were given periodic electric shocks antemortem. The same treatment increased juiciness in cooked psoas major ($P<.05$) and quadriceps femoris ($P<.01$) muscles. Cattle stimulated by electric shock produced a less tender longissimus muscle and less expressible water from psoas major and quadriceps femoris muscles (Lewis et al., 1962c). Lewis et al. (1965) reported no effect on tenderness of the longissimus muscle but significantly ($P<.01$) increased tenderness of psoas major and quadriceps femoris muscles from steers given electric shocks pre-slaughter. Juiciness was increased only in the psoas major ($P<.05$) muscle.

Pigs, stressed by exercise, showed musculature which appeared dark, firm and dry (Briskey et al. 1959a,b). Gilts exercised three hours (1 mile per hour) prior to slaughter had darker colored gluteus medius muscles than unstressed controls. However Briskey et al. (1959a) stated that hogs similarly exercised over a four day period evidently adjusted and yielded carcasses with normal colored muscle tissue. Lambs exercised to near exhaustion were found to have significantly ($P<.05$) darker colored rectus abdominus muscles (Forrest et al., 1961).

Pigs suffering from what was called muscle degeneration disease showed no increase in blood lactic acid during exercise (Ludvigsen, 1957). Howard and Lawrie (1957) suggested there would be little or no change in ultimate postmortem muscle pH of steers given short-term pre-slaughter exercise if the rate of diffusion of lactic acid from active muscles to the blood stream was slow.

According to Forrest et al. (1961), severe exercise significantly increased the pH of lamb rectus abdominus and intercostal muscles ($P<.001$) and longissimus muscles ($P<.05$). Similar results were reported by Briskey et al. (1959a,b) in pigs exercised prior to slaughter. Stressed pigs were found to have significantly higher muscle pH postmortem (P<.01) which resulted in greater muscle water-holding capacity.

No tenderness differences were found in organoleptic evaluation of longissimus muscles from lambs exercised on a treadmill preslaughter (Forrest et al., 1964).

The relationship of season to the incidence of dark, firm and dry or pale, soft and watery pork ham muscles was investigated by Forrest, Gundlack and Briskey (1963). Season and muscle color were significantly (P<.01) related with a higher incidence of normal colored hams occurring in winter and summer than in spring and fall. Less daily temperature variation in winter and summer was thought to account for the higher rate of normal colored hams. Dark hams appeared more often in winter and spring while pale, soft and watery hams were more common during summer high temperatures as well as during periods of wide fluctuations of environmental temperature.

Pigs were placed in ice cold water for 30 minutes by Sayre et al. (1961) to simulate a severe environmental change. Kastenschmidt et al. (1964, 1965) placed pigs in a climatically controlled chamber to observe the effects of preslaughter environmental temperature on pork muscle properties. All three investigations revealed cold treatment resulted in darker colored pork muscles, decreased postmortem lactic acid production, increased muscle pH and improved water-holding capacity of the muscle tissue. According to Kastenschmidt et al. (1964) the most desirable muscle properties were obtained from warm treatment followed immediately by cold treatment. Muscle was extremely pale, soft and exudative after warm treatment prior to slaughter which agrees with the findings of Judge _et al_. (1968a) and Forrest _et al_. (1968).

Lawrie (1958) maintained that high ultimate pH was of major importance in dark colored muscle. Hedrick _et al_. (1959) reported that the development of dark-cutting beef depended on intensity and duration of the stress and animal susceptibility to stress. Differences in muscle properties between bright and dark colored beef were highly associated with variation in lactic acid concentration (Hall, Latschar and Mackintosh, 1944). Analysis of dark (pH 6.24) and bright (pH 5.44) beef rib eye samples revealed lactic acid concentrations of 613 mg/100g and 989 mg/100g of tissue, respectively. Wismer-Pedersen (1959), in work with Danish Landrace pigs, confirmed that postmortem pH and lactic acid concentration were closely related (-.86 correlation). Swift, Berman and Gibbs (1958) declared water-holding capacity of postmortem muscle was a function of pH. Water-holding capacity and pH were found to have a 0.62 correlation according to Judge _et al_. (1958) and Briskey _et al_. (1960) noted that pork muscles with the lowest postmortem pH had the lowest water-holding capacity. Judge _et al_. (1958) also reported dark, firm pork tissue to be less tender than pale, soft tissue. This was supported by a significant ($P<.01$) negative relationship between taste panel tenderness scores and postmortem muscle pH. Contrary observations were noted by Webb, Kahlenberg and Naumann (1959) who described steaks from stressed steers as more tender than those from nonstressed steers in early stages of aging.

Prolonged stress generally has the same effect on various properties of postmortem musculature of beef, lamb and pork. Muscle color is usually darkened and lactic acid production is decreased with a resultant postmortem pH above normal. Water-holding capacity appears to increase with a muscle pH increase and tenderness is often increased.

THIS BOOK CONTAINS NUMEROUS PAGES WITH MULTIPLE PENCIL AND/OR PEN MARKS THROUGHOUT THE TEXT.

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Chapter III

AUDITORY THRESHOLDS OF BEEF CATTLE

Summary

Auditory thresholds were established for cattle. A total of 525 observations were made on two groups of Hereford steers with thresholds measured at selected frequencies ranging from 250 Hz (hertz) to 20,000 Hz. Methods to determine thresholds (respiration pattern changes and behavioral responses) were highly correlated ($r = 0.97$). Lowest threshold was found at 8,000 Hz.

Introduction

Technological advances have been accompanied by increased noise or what Stevens and Warshofsky (1965) called "unwanted sound." Experts in psychological acoustics found humans may be affected very little by noise or they may be extremely irritated by it. Despite this, little research has been reported on the effect of noise on meat animals, particularly beef cattle. To study the effect of noise on beef cattle it was necessary to determine their auditory thresholds. Auditory thresholds have been measured for the cat (Neff and Hinds, 1955); chimpanzee (Elder, 1933); dog (Lipman and Grassi, 1942); rat (Henry, 1935 and Gould and Morgan, 1942); sheep (Ames and Arehart, 1972) and other animals, but thresholds for beef cattle have not been reported.

Experimental Procedure

Data for the auditory threshold curve were obtained from two groups of Hereford steers (408.2 to 476.3 kg) maintained in a dry lot with no preconditioning. Group 1 (12 steers) was tested at sound frequencies of 250 Hz (hertz) through 12,000 Hz and Group 2 (11 steers) at 12,000 Hz through 20,000 Hz.

Group 1 was tested in a semi-soundproofed 2.4 m X 2.4 m chamber in a thermally controlled room (20^{o}C). The chamber ceiling and interior walls were constructed of two 3.8 cm layers of styrofoam. A 7.6 cm dead air space separated interior and exterior walls with the latter made of one 3.8 cm layer of styrofoam covered with rock wool insulation and a fiber board layer. A layer (4 cm) of dried wood chips covered the floor. Steers were observed through a 30.48 cm^2 one-way window. Background sound intensity in the chamber was 23 decibels (decibel [dB] is a logarithmic ratio of power or intensity level with reference to a sound pressure level of 0.0002 dynes per cm^2) measured using Scale C of a sound level meter (General Radio Company, Model 1551-C). Group 2 was tested in a 1.8 m X 2.4 m curtained area in a concrete block room with burlap-draped walls. Curtains were rock wool insulation and burlap. Animals were observed through a small opening in the curtain. Background noise in the curtained area was 35 dB.

Sound frequencies 250 Hz through 12,000 Hz (Group 1 steers) were produced by an audiometer (Maico, Model F-1) and 12,000 Hz through 20,000 Hz (Group 2 steers) by an audio generator (Heathkit, Model IG-72). Two earphones were constructed by inserting the audiometer speakers into silicone molds shaped to conform to the interior surface of the steers' ears. Earphone power output was measured in decibels using Scale C on a sound level meter (General Radio Company, Model 1551-C). The earphones taped securely in the steers' ears helped reduce background noise.

Sound distortions were found in the audio system using an oscilloscope (Heath, Model 10-12) and are shown in table 1. No distortions occurred at the decibel levels studied.

TABLE 1. DECIBEL LEVELS AT WHICH SOUND DISTORTIONS OCCURRED

Frequency (Hz)	Decibels
250	85
500	100
1,000	100
1,500	100
2,000	100
3,000	100
4,000	100
6,000	100
8,000	100
12,000	100
14,000	76
16,000	76
18,000	73
20,000	75

Auditory sensitivity was determined by (1) behavioral responses and (2) changes in respiration with a different person interpreting each kind of response. Behavioral responses of pricking the ears and turning or lifting the head were interpreted as recognition of auditory stimuli. A thermal detector (E & M Respiration Thermistor Probe) was placed centrally in one nostril and respiration patterns were recorded using a telemetry system (E & M Physiograph) and rectilinear strip chart recorder. Altered respiration rate or reduced amplitude of respiration was interpreted as auditory stimuli perception. Similar respiration responses to auditory stimuli have been reported for dogs, rabbits and frogs (Corbeille and Baldes, 1929) and cats (Wever, 1930).

All frequencies were selected at random with Group 1 being tested at frequencies shown in table 1 up to and including 12,000 Hz and Group 2 at frequencies shown in table 1 from 12,000 Hz to 20,000 Hz. Each frequency was presented for four- to five-second periods at increased intensity levels until animal responses indicated perception of the stimuli. A minimum of five minutes were allowed between each frequency test and each steer was tested three times at each frequency.

Data were statistically analyzed using analysis of variance and Duncan's Multiple Range Test (Kramer, 1956).

Results

Significant differences ($P<.05$) were found between steers at all frequencies studied. Means and standard deviations for each steer at the different frequencies are shown in table 2. Standard deviations were highest at lower frequencies and lowest at higher frequencies with standard deviations being higher in group one than group two.

Auditory thresholds gradually decreased from 250 Hz to 1,000 Hz then increased as frequency increased to 2,000 Hz. Subsequent thresholds declined to the lowest point at 8,000 Hz then increased as frequency reached 20,000 Hz. Several steers appeared to experience physical discomfort when exposed to auditory stimuli of 20,000 Hz.

Respiration and behavioral responses to auditory stimuli were highly correlated ($r = 0.97$).

Discussion

The auditory sensitivity of beef cattle and the noises surrounding them may significantly influence their homeostatic state. Slaughter cattle moved from feedlot to packing plant are an example of cattle that may be severely stressed. It is logical to assume new sounds or noises

TABLE 2. AUDITORY THRESHOLDS FOR STEERS IN DECIBELS[1,2]

Steer Number	Frequency (Hz) 250	500	1000	1500	2000	3000	4000	6000	8000	12000[3]
Group 1:										
1	66.7^{abcd} ±26.0	59.0^{ab} ±10.6	61.5^{a} ±13.6	55.7^{ab} ±8.0	53.0^{abcd} ±8.4	50.7^{bc} ±5.8	45.3^{b} ±5.5	41.0^{b} ±3.5	32.3^{cd} ±14.6	25.5^{ef} ±5.8
2	63.5^{abcde} ±28.4	52.2^{b} ±7.8	55.3^{ab} ±4.4	51.8^{ab} ±4.5	60.2^{abc} ±6.5	51.3^{bc} ±8.5	51.0^{b} ±7.7	35.3^{b} ±19.5	31.7^{cd} ±17.4	18.5^{f} ±10.1
3	70.2^{abc} ±9.5	51.3^{b} ±9.5	46.0^{bc} ±0.0	45.2^{b} ±8.0	42.2^{cd} ±2.0	50.5^{bc} ±7.4	43.8^{b} ±8.9	36.0^{b} ±8.9	35.5^{cd} ±2.7	32.3^{cdef} ±8.8
4	86.8^{a} ±21.6	69.0^{a} ±10.0	54.8^{ab} ±12.1	66.3^{a} ±13.2	71.3^{a} ±29.8	56.8^{bc} ±17.4	49.5^{b} ±5.8	56.8^{b} ±16.3	34.7^{cd} ±5.2	41.3^{abcde} ±17.4
5	76.3^{ab} ±17.2	70.0^{a} ±7.1	44.0^{bc} ±5.6	58.3^{ab} ±8.4	53.8^{abcd} ±8.0	62.2^{ab} ±3.5	46.7^{b} ±4.9	35.2^{b} ±8.6	20.5^{d} ±9.9	33.8^{bcdef} ±5.1
6	76.7^{ab} ±32.6	57.7^{ab} ±8.3	42.2^{bc} ±4.4	55.2^{ab} ±11.1	51.3^{abcd} ±11.3	44.7^{c} ±10.7	51.7^{b} ±7.8	38.8^{b} ±6.3	27.2^{d} ±4.9	29.7^{def} ±7.6
7	26.5^{e} ±4.2	43.3^{bc} ±1.6	52.3^{ab} ±0.5	53.2^{ab} ±10.5	66.0^{ab} ±11.2	51.2^{bc} ±8.5	52.7^{b} ±13.4	53.2^{b} ±11.7	52.7^{abc} ±13.8	49.0^{ab} ±6.7
8	31.0^{de} ±13.9	23.3^{d} ±5.7	20.2^{d} ±4.4	47.7^{ab} ±14.4	61.3^{abc} ±9.3	71.3^{a} ±9.3	77.5^{a} ±15.3	84.3^{a} ±23.9	62.8^{ab} ±8.6	53.7^{a} ±0.8
9	33.0^{cde} ±7.3	33.7^{cd} ±12.3	42.8^{bc} ±3.8	41.8^{b} ±2.0	51.3^{abcd} ±6.1	46.7^{c} ±2.1	58.2^{b} ±7.7	54.2^{b} ±9.1	41.3^{bcd} ±10.3	39.3^{abcde} ±9.4
10	27.8^{e} ±10.6	44.3^{bc} ±5.1	45.0^{bc} ±6.2	44.3^{b} ±2.6	39.7^{d} ±2.6	43.0^{c} ±9.6	47.0^{b} ±15.6	49.7^{b} ±7.4	43.5^{abcd} ±12.7	26.5^{ef} ±3.3

TABLE 2 CONT. AUDITORY THRESHOLDS FOR STEERS IN DECIBELS[1,2]

Steer Number	Frequency (Hz) 250	500	1000	1500	2000	3000	4000	6000	8000	12000[3]
11	43.7^{bcde} ±5.7	35.5^{cd} ±7.9	47.8^{bc} ±5.9	46.8^{b} ±11.6	38.8^{d} ±5.8	50.5^{bc} ±3.5	54.5^{b} ±13.6	57.0^{b} ±14.9	66.3^{a} ±13.4	52.3^{a} ±23.3
12	42.0^{bcde} +3.1	26.0^{d} +4.5	37.0^{c} +0.0	38.8^{b} +6.5	48.0^{bcd} +6.3	48.0^{c} +8.0	42.0^{b} +0.0	40.7^{b} +10.7	33.3^{cd} +16.0	48.0^{abc} +10.0
Mean	53.7 ±21.9	47.1 ±15.5	45.7 ±10.5	50.4 ±7.8	53.1 ±10.2	52.2 ±7.9	51.7 ±9.4	48.5 ±14.1	40.2 ±14.0	43.4 ±10.5

Steer Number	Frequency (Hz) 12000[3]	14000	16000	18000	20000
Group 2:					
13	49.7^{ab} ±0.5	52.7^{bc} ±0.5	58.5^{bc} ±0.5	68.3^{b} ±0.5	73.2^{bc} ±1.3
14	51.2^{a} ±0.8	58.3^{a} ±0.4	62.3^{a} ±0.5	71.8^{a} ±1.2	75.7^{a} ±1.3
15	53.7^{a} ±0.5	58.0^{a} ±1.5	62.8^{a} ±0.8	72.5^{a} ±0.5	75.8^{a} ±1.0
16	54.2^{a} ±0.5	58.2^{a} ±1.2	62.2^{a} ±2.6	72.3^{a} ±0.5	75.2^{ab} ±0.4
17	48.3^{abc} ±0.5	52.7^{bc} ±0.5	57.0^{cd} ±0.9	66.0^{c} ±0.9	70.0^{e} ±1.5
18	49.2^{ab} ±1.0	53.0^{bc} ±1.0	58.2^{bc} ±0.4	67.0^{bc} ±0.6	71.5^{cde} ±1.5

TABLE 2 CONT. AUDITORY THRESHOLDS FOR STEERS IN DECIBELS[1,2]

Steer Number	Frequency (Hz) 12000[3]	14000	16000	18000	20000
19	48.7^{ab} ±0.5	52.7^{bc} ±1.0	58.0^{bc} ±0.9	67.0^{bc} ±0.9	71.5^{cde} ±1.8
20	50.2^{ab} ±0.4	53.0^{bc} ±0.0	57.7^{bc} ±0.5	65.7^{c} ±1.0	70.0^{e} ±1.8
21	49.2^{ab} ±1.0	52.7^{bc} ±0.5	57.0^{cd} ±0.9	65.7^{c} ±0.5	69.8^{e} ±0.4
22	43.7^{abcd} ±4.1	51.7^{c} ±0.5	56.0^{d} ±0.0	65.7^{c} ±0.5	70.5^{de} ±0.5
23	51.3^{a} ±1.0	53.7^{b} ±0.5	58.8^{b} ±0.4	67.5^{b} ±0.5	72.8^{cd} ±1.0
Mean	43.4 ±10.5	54.2 ±2.6	59.0 ±2.4	68.1 ±2.7	72.4 ±2.3

[1]Decibel levels are means of three observations.
[2]All animal means within columns with same superscript letter are not significantly different ($P<.05$).
[3]Overall mean decibel level includes observations of Groups 1 and 2 and footnote 2 applies to the two groups combined.

the animal hears during such movement add to the stress effect. Extent of sound stress likely depends on the auditory sensitivity of the cattle. The minimum audible field for the steers tested is shown in figure 2.

Audiologists reference human auditory thresholds to a standard threshold curve adopted in 1964 by the International Standardization Organization. The threshold curve (figure 1) is the ISO Reference Audiometric Zero (Davis and Kranz, 1964) and human hearing test results are expressed as being above or below this standard curve. The auditory thresholds (figure 2) for steers are referenced to a sound pressure level of absolute zero. Results of the steer hearing tests cannot be compared to an audiometric zero for cattle since a standard curve has not been reported. Additional tests on a larger number of cattle must be completed before a standard auditory threshold curve (audiometric zero) for beef cattle may be established.

Ames and Arehart (1972) reported an auditory threshold curve for sheep (figure 3) and found the greatest sensitivity at 7,000 Hz (7.3 dB absolute sound pressure level above background noise).

The auditory threshold curve of steers (figure 2) is generally shaped the same as the curve for sheep (figure 3) and partially resembles the curve for humans (figure 1). Beef cattle appear to be less sensitive to low frequency stimuli than both sheep and humans. Maximum acuity is at a higher sound frequency (8,000 Hz) in beef cattle as compared to sheep (7,000 Hz) and humans (1,500 Hz) however, sheep and humans perceive the 8,000 Hz stimuli at lower sound pressure levels (8.2 dB above background noise and 9.0 dB, respectively) than do beef cattle (40.2dB).

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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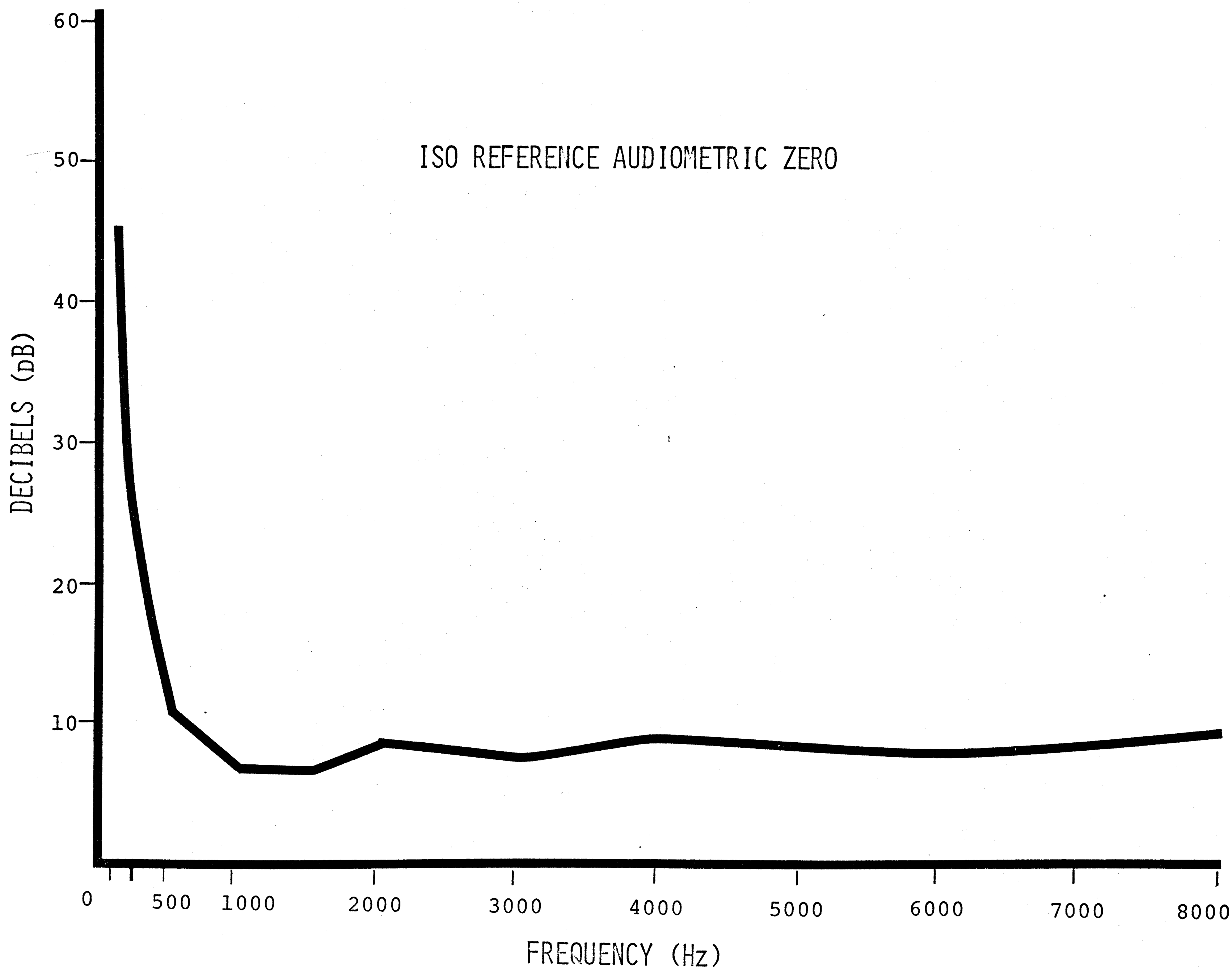
ISO REFERENCE AUDIOMETRIC ZERO
DECIBELS (dB)
60
50
40
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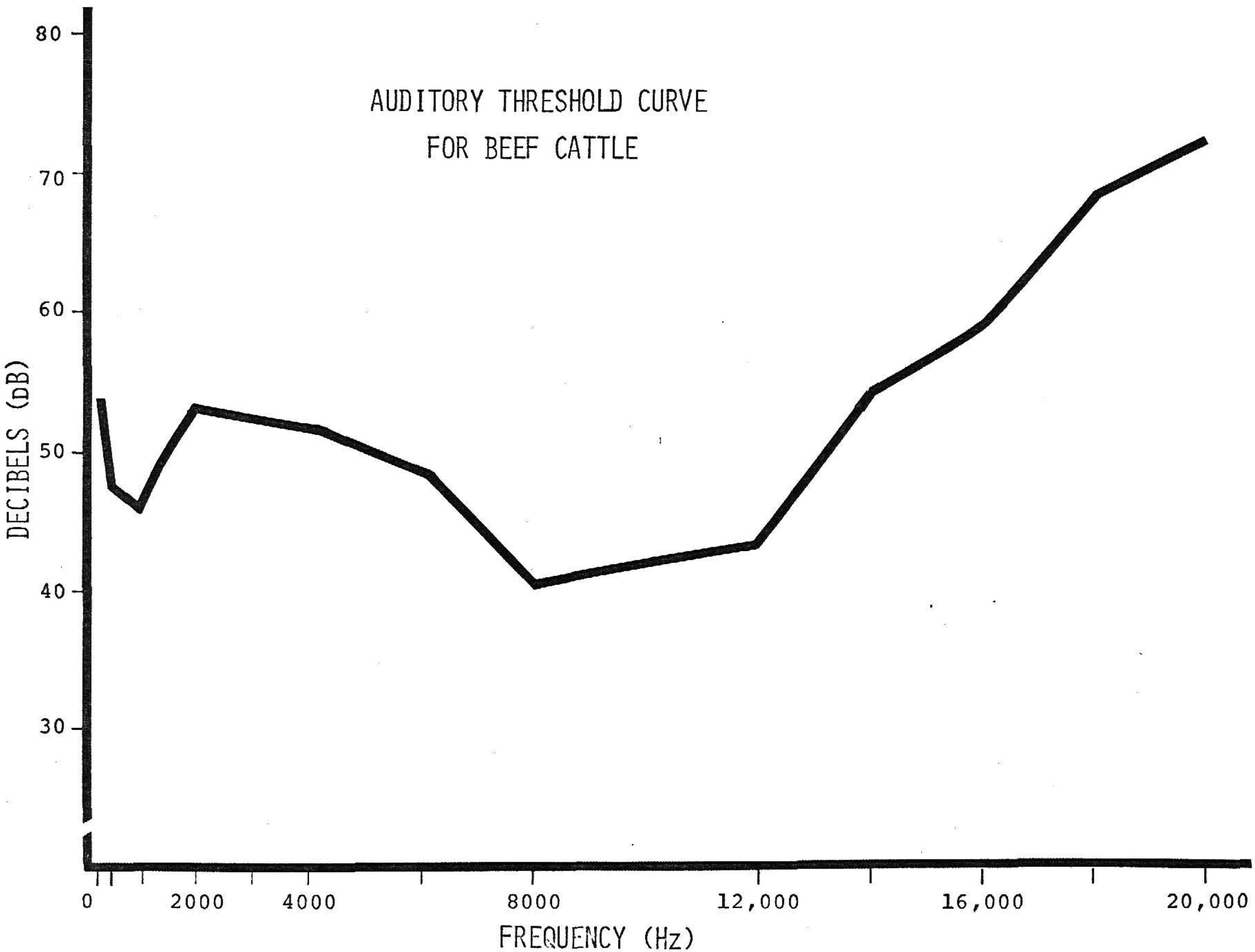
8000
FREQUENCY (Hz)

Figure 1



AUDITORY THRESHOLD CURVE
FOR BEEF CATTLE
DECIBELS (dB)
80
70
60
50
40
30
0
2000
4000
8000
12,000
16,000
20,000
FREQUENCY (Hz)

Figure 2

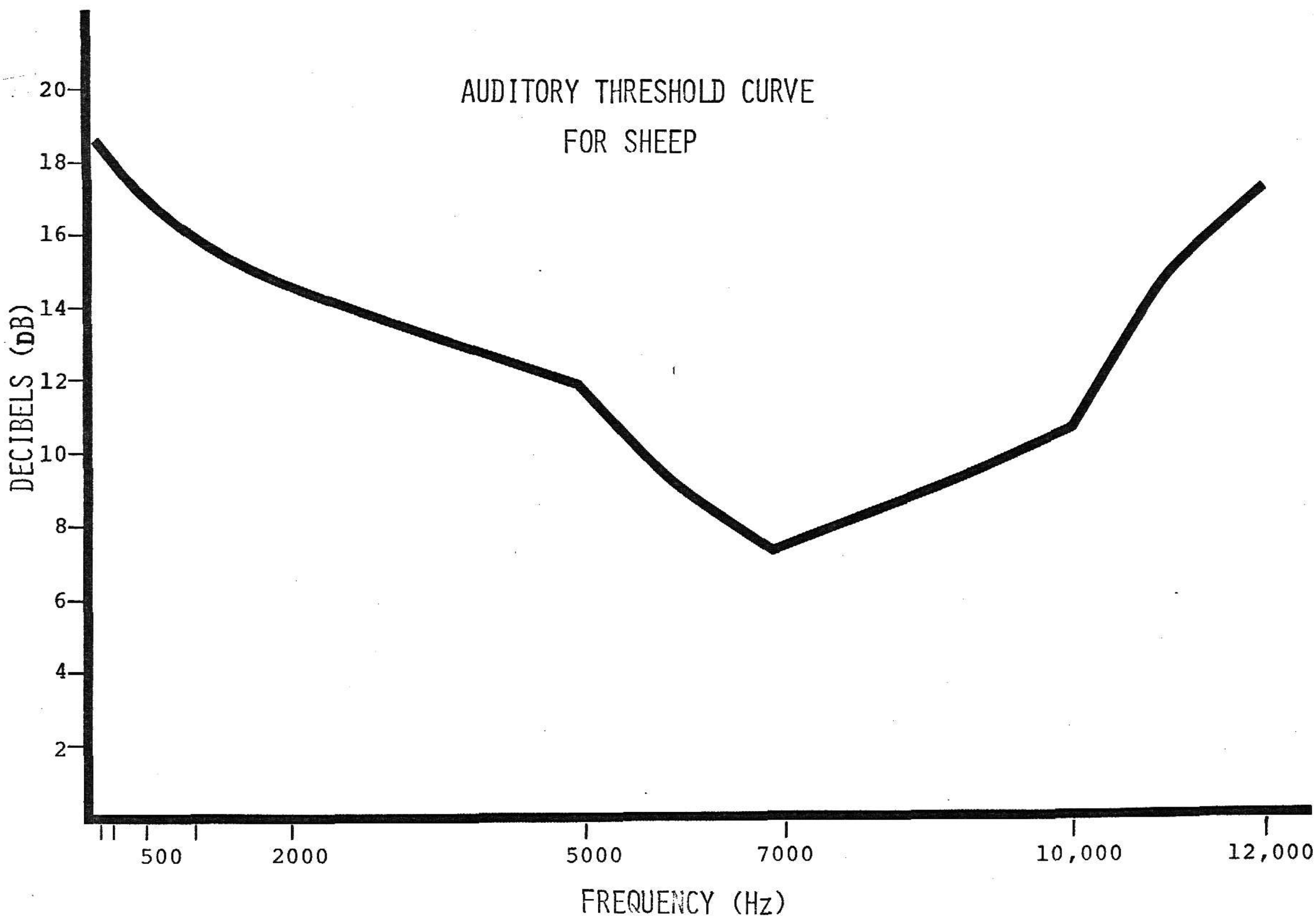

AUDITORY THRESHOLD CURVE
FOR SHEEP
DECIBELS (dB)
20
18
16
14
12
10
8
6
4
2
500
2000
5000
7000
10,000
12,000
FREQUENCY (Hz)

Figure 3

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Chapter IV

EFFECT OF SOUND STRESS ON ADRENAL GLAND WEIGHT AND MUSCLE QUALITY OF BEEF CATTLE

Summary

Three groups of beef cattle were stressed prior to slaughter by exposure to intermittent loud noises. Group 1 (13 cattle) was stressed 12 hours at maximum sound intensity of 96 dB (decibels), Group 2 (6 cattle) 12 hours at 106 dB maximum loudness and Group 3 (6 cattle) 24 hours at 106 dB. No significant differences were found in adrenal gland weight or postmortem Longissimus muscle pH, lactic acid content, water-holding capacity or tenderness. Subjective color scores of Longissimus muscle samples showed Group 3 samples significantly ($P<.05$) darker than controls while Groups 1 and 2 were darker but not significant. Spectrophotometric reflectance ratios for 474nm/525nm were significantly ($P<.01$) lower for Groups 2 and 3 than the control group. Reflectance values were also significantly different at 525nm (higher) and 600nm (lower) in Groups 2 ($P<.01$) and 3 ($P<.05$) and at 630nm (lower) in Group 2 ($P<.05$).

Introduction

Endocrine responses to stress have been extensively investigated using laboratory animals (Hale, 1952; Ingle, 1952; Anthony and Ackerman, 1955 and Sackler et al., 1959) but very little work is reported with large animals (Judge and Stob, 1963). Numerous researchers (Hedrick, Brady and Turner, 1957; Lewis, Heck and Brown, 1961 and Forrest, Merkel and Mackintosh, 1964) studied the effect of different kinds of antemortem stresses on postmortem muscle quality of meat animals. None of these investigators used sound as the antemortem stressor.

Experimental Procedure

Twenty-five beef cattle were subjected to intermittent loud noises at different time periods and intensity levels. Thirteen animals comprised Group 1--nine Hereford steers, one Angus steer, two Hereford cows and one Hereford heifer. Group 2 was one Hereford steer and five Angus steers and Group 3 included three Hereford steers and three Angus steers. The control group was four Hereford steers, one Angus steer and one Hereford bull.

Noises used to stress the cattle were recorded on a continuous playing tape and included cannons, jet planes, sirens, people cheering, cattle bawling, an air hammer, trains, a parade and heavy trucks. Silent periods of two to ten minutes randomly separated the recorded noises.

All cattle stressed were confined in individual pens 0.7m X 2.8m adjacent to the slaughter facility. Two speakers (Heath, Model AS-48) were suspended 2.44m above the floor and directed toward the cattle. Group one cattle were stressed 12 hours at a maximum sound intensity of 96 dB (decibels). Groups 2 and 3 were stressed 12 and 24 hours, respectively, at a maximum sound intensity of 106 dB. The cattle were slaughtered immediately after the stress period.

Following evisceration, both adrenal glands were removed, trimmed of adjoining fatty tissue and weighed. All carcasses were chilled 48 hours, then two 2.54cm thick *Longissimus* muscle samples were removed from the thirteenth rib area of the left side of each carcass.

The first sample removed was allowed 30 minutes to bloom then muscle color was subjectively scored and scanned at wavelengths of 400nm to 700nm using a reflectance spectrophotometer (Bausch and Lomb, Model 600) with a magnesium oxide block as reference and a scan speed of

250nm/min. Subjective scores were assigned using a scale of 1 to 5 when 1 = very bright, 3 = slightly dark and 5 = extremely dark. Reflectance values were measured at 474nm, 525nm, 600nm, 630nm and the ratio 474/525nm. The sample was frozen for later tenderness and water-holding capacity determinations. The second Longissimus muscle sample was ground three times through a one-eighth inch plate and frozen for subsequent determination of pH and lactic acid content.

Lactic acid content was determined by a modification of the method of Barker and Summerson (1941) and water-holding capacity by the Wierbicki and Deatherage (1958) modification of the Grau and Hamm (1953) press procedure. Tenderness was evaluated by the Warner-Bratzler shear machine. The samples were cooked to 65.5°C internal temperature in a 176.6°C oven, allowed to cool to room temperature, one-half inch cores were removed and shear values obtained. Muscle pH was determined by blending a 10g ground sample in 100 ml distilled water then measuring pH with a Beckman Expandomatic pH Meter.

All data were analyzed using one-way analysis of variance (Snedecor and Cochran, 1971).

Results

No significant differences were found in adrenal gland weight, postmortem muscle pH, lactic acid content, water-holding capacity or tenderness of Longissimus muscle between the control and stressed groups of cattle (Table 1).

Subjective color scores of 2.92 and 1.92 for Group 3 and Control group, respectively, showed Longissimus muscle color was significantly ($P<.05$) darker in the stressed cattle. Subjective scores for stressed

TABLE 1. MEANS AND STANDARD DEVIATIONS OF ADRENAL GLAND WEIGHT AND POSTMORTEM MUSCLE PH, LACTIC ACID CONTENT, WATER-HOLDING CAPACITY AND TENDERNESS OF CONTROL AND STRESSED CATTLE

		Stressed		
	Control	Group 1	Group 2	Group 3
Adrenal gland weight (g)	17.88 ±3.76	19.61 ±3.48	19.97 ±3.77	17.28 ±2.79
pH	5.55 ±.11	5.54 ±.11	5.58 ±.04	5.60 ±.02
Lactic acid[1] (ug/g)	641.00 ±169.75	641.08 ±167.76	669.33 ±302.67	710.00 ±57.27
Water-holding capacity[2]	17.43 ±.93	16.96 ±.98	17.69 ±1.83	19.70 ±1.13
Tenderness[3]	7.00 ±2.62	7.50 ±4.91	7.00 ±2.53	6.27 ±1.52

[1]Lactic acid content is expressed as ug of lactate per g of fresh tissue.
[2]Water-holding capacity expressed as square inches of juice area per g of tissue.
[3]Tenderness expressed as pounds of force required to shear a one-half inch core in a Warner-Bratzler Shear.

Groups 1 (2.46) and 2 (2.63) indicated darker muscle color than the Control group (1.92) but were not statistically significant (Table 2).

Reflectance spectrophotometer results showed significantly ($P<.01$) lower 474/525nm values for Groups 2 (0.78) and 3 (0.77) than for the Control (1.15). Reflectance percentages were significantly different at 525nm and 600nm in Groups 2 ($P<.01$) and 3 ($P<.05$) and at 630nm in Group 2 ($P<.05$).

Discussion

The dark purple red color characteristic of dark cutters varies in degree of darkness according to prolongation and severity of pre-slaughter stress. One response to stress is increased secretion of epinephrine. Epinephrine stimulates mobilization of glycogen stores in

TABLE 2. MEANS AND STANDARD DEVIATIONS OF SUBJECTIVE COLOR SCORES AND PERCENT REFLECTANCE OF LONGISSIMUS MUSCLE SAMPLES FROM CONTROL AND STRESSED CATTLE

		Stressed		
	Control	Group 1	Group 2	Group 3
Subjective score[1]	1.92 ±.74	2.46 ±.66	2.63 ±.78	2.92 ±.58
474 nm	12.15 ±1.00	11.17 ±3.52	9.90 ±1.08	11.02 ±2.40
525 nm	10.58 ±1.30	10.34 ±3.56	12.77** ±.86	14.25* ±2.93
600 nm	17.55 ±2.30	15.12 ±5.47	11.67** ±1.40	13.57* ±2.95
630 nm	31.87 ±3.43	28.92 ±5.57	27.45* ±2.88	30.02 ±4.28
474/525 nm	1.15 ±.05	1.09 ±.11	0.78** ±.04	0.77** ±.03

[1]Subjective scores are based on the scale: 1 = very brignt, 2 = bright, 3 = slightly dark, 4 = dark, and 5 = extremely dark.

*P<.05 difference from control.

**P<.01 difference from control.

liver and skeletal muscle tissue resulting in higher levels of lactic acid production. Lactate is removed from the blood stream by liver cells to form glucose in an attempt to supply the animal with energy to withstand the stressful condition. After prolonged antemortem stress anerobic metabolism that normally continues in muscle tissue following exsanguination is severely limited due to depletion of muscle glycogen reserves. Lactic acid production in postmortem muscle tissue decreases in accordance with muscle glycogen depletion and results in higher than normal postmortem muscle pH.

Water-holding capacity of postmortem muscle increases with pH. Muscle fibers swell or become more turgid as water content increases thus reducing oxygen permeability between muscle fibers. Inability of oxygen to penetrate the muscle surface prevents development of desirable muscle color and results in dark cutting carcasses.

Conclusions

Results of this study showed loud noise does stress beef cattle to the extent that postmortem muscle color is darker than normal which concurs with observations of Kropf, Ames and Arehart (1973) who found darker colored flank muscle in sound stressed lambs. The results also indicated sound stress must last at least 24 hours to cause dark cutting carcasses agreeing with the conclusion of Hedrick et al. (1959). Longissimus muscle color of cattle stressed 24 hours (Group 3) was noticeably darker but not dark enough to create a serious wholesale or retail merchandising problem.

While not significant, postmortem pH values increased slightly as noise loudness and exposure time increased and were accompanied by a nonsignificant increase in lactic acid content which is opposite that reported by other researchers. Increased lactic acid levels suggest less muscle glycogen reserves were mobilized as stress became more severe. However, the magnitude of lactate content changes was not great enough to strongly influence muscle pH.

Water-holding capacity showed no consistent relationship to muscle pH or lactic acid content but was lowest in samples from the most severely stressed group which contained the most lactate.

Cattle in this study were not transported great distances prior to slaughter as is common in slaughter animals moving from feedlot to packing plant. The stress of sound in addition to the stress of transportation might alter the results observed in this study. The cattle were confined in individual pens during the pre-slaughter stress period. Freedom of movement would have allowed the animals to become more excited and may have resulted in darker colored postmortem muscle.

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EFFECT OF SOUND STRESS ON BEEF CARCASS QUALITY

by

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B.S., Kansas State University, 1966

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

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ABSTRACT

EFFECT OF SOUND STRESS ON BEEF CARCASS QUALITY

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The effect of sound stress on beef carcass quality was studied by initially determining auditory thresholds for beef cattle at selected frequencies between 250 Hz (hertz) and 20,000 Hz. Respiration pattern changes and behavioral responses were used to determine hearing thresholds ($r = 0.97$). The lowest hearing threshold (40.2 dB) was found at 8,000 Hz.

Twenty-five beef slaughter cattle were stressed by intermittent loud noises. The antemortem stress period for Groups 1 and 2 was 12 hours with a maximum sound intensity of 96 dB and 106 dB, respectively. Group 3 was stressed 24 hours at a maximum loudness of 106 dB. No significant differences between control and stressed groups of cattle were found for adrenal gland weight or postmortem *Longissimus* muscle pH, lactic acid content, water-holding capacity or tenderness. Subjective color scores of *Longissimus* muscle samples showed significantly darker color in Group 3 ($P<.05$) than in the Control Group. Spectrophotometric reflectance values were significantly higher than the Control Group at 525 nm in Groups 2 ($P<.01$) and 3 ($P<.05$) and significantly lower at 600 nm in Groups 2 ($P<.05$) and 3 ($P<.01$). Group 2 reflectance values at 630 nm were significantly lower ($P<.05$) than the Control Group and the reflectance ratio 474/525 nm of Groups 2 and 3 were significantly lower ($P<.01$) than the Control Group.