Factors Affecting Forage Intake by Range Ruminants: A Review

C.D. ALLISON

Abstract

Variation in voluntary forage intake is undoubtedly the major dietary factor determining level and efficiency of ruminant production. This variation is largest and least predictable for grazing ruminants. Range ruminant productivity and efficiency is relatively low due, in part, to intake limitations; therefore, productivity could probably be increased most by increasing intake. Most available literature points to digestibility and rate of ingesta passage and reticulo-rumen fill as primary mechanisms of intake regulation in range ruminants. Body size and physiological status of ruminants appear to have the largest effect of animal-related factors in governing level of voluntary intake. Kind and amount of supplementation, forage availability, and grazing intensity are major management-controlled variables affecting intake by domestic range ruminants.

Animal nutrition has generally been recognized as being dependent upon 4 basic factors: the animal's requirements, nutrient content of the feedstuff, digestibility of the feedstuff, and how much the animal will consume.

Range ruminant nutrition has unique characteristics and problems. Nutrient requirements of range livestock are not known because requirements can be altered by grazing activity, travel, and environmental stresses such as temperature extremes. Nutritive value and digestibility are also difficult to determine because animals select their diet from various combinations of plant species and plant parts. The most critical factor in meeting nutrient requirements of a grazing ruminant is knowledge of how much it will voluntarily consume. Conceptually, if an animal could eat enough, it could satisfy its nutrient requirements on low-quality forages. But total intake is limited by physical factors of the animal and plant, animal physiological factors, and management strategies of the plant-animal interface.

Crampton (1957) felt the value of a forage in animal production depends more on the amount consumed than its chemical composition. This concept led to the nutritive value index for forages, based on their voluntary intake and digestibility (Crampton et al. 1960).

Reviews on methodology to determine forage intake by range ruminants include those by Cordova et al. (1978) and Kartchner and Campbell (1979). Reviews on methodology to determine range herbivore diets are available by Theurer et al. (1976), Van Dyne et al. (1980), Holechek et al. (1981, 1982), Harris et al. (1967), Harris (1968), and Van Dyne (1969).

Author is extension management specialist, New Mexico State University, Las Cruces 88003.
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This review compiles findings regarding physical, physiological and management factors that are known to affect or regulate voluntary intake of range livestock.

Regulation of Voluntary Intake

Control of feed intake and regulation of energy balance in ruminants were extensively reviewed at the Third International Ruminant Symposium (Arnold 1970a, Baumgardt 1970, Campling 1970) and more recently reviewed by Baile and Forbes (1974). In a review by Baile (1975), several intake-controlling mechanisms were discussed. Included were humoral factors, neural transmitters, and chemical and hormonal mechanisms, as well as digestibility, reticulo-rumen fill, and rate of passage. The effect of oral and abomasal infusions of volatile fatty acids on feed intake has been recently studied by Papas and Hatfield (1978).

The bulky, fibrous nature of most range ruminant diets, and their relatively low content of digestible energy, lends emphasis to the importance of the physical effect of gut distention in limiting voluntary intake. Considerable evidence is available showing, with predominantly roughage diets, voluntary intake is limited by capacity of the reticulo-rumen and by rate of disappearance of digesta from this organ (Balch and Campling 1962, Ellis 1978). Rate of disappearance depends on rate of passage and rate of absorption.

Voluntary food intake is limited by physical conditions within the gut and particularly by amount of digesta in the reticulo-rumen. Studies concerning effects on voluntary intake of intraruminal additions or removals of food and other materials, relationship between rumen-fill and voluntary intake, and relationship between rate of disappearance of digesta and voluntary intake, support the previous statement and were reviewed by Campling (1970).

Removing swallowed hay as it entered the reticulo-rumen showed hay accumulation in the rumen exerted an immediate effect on termination of eating by cows. Cows could be encouraged to eat for much longer than normal periods by removing swallowed hay. Conversely, addition of digesta, consisting of recently ingested hay, to the rumen of cows during a meal caused an immediate decrease in hay intake (Campling and Balch 1961). Confirmation of these results is provided by Weston (1966), who conducted experiments with a sheep offered chopped roughages. In this study coarsely ground roughage, sawdust, and finely ground polyvinyl chloride were introduced into the rumen.

In general, ruminants try to compensate for the inclusion of finely milled inert material in concentrate diets by an increased total intake (Baile and Pfander 1964, Boling et al. 1967).

When ruminants are offered roughages such as hay and dried grass, there is evidence that cattle and sheep eat to a constant rumen fill. Blaxter et al. (1961) showed that sheep offered poor, medium, and good hays had similar dry matter contents in the digestive tract. Ulyatt et al. (1967) provided further confirmation of these findings. Campling and Balch (1961) removed and weighed digesta in the reticulo-rumen after meals of hay and dried grass. Eating ceased when the reticulo-rumen contained similar amounts of dry matter. Quantity of each roughage eaten was directly related to its rate of disappearance from the reticulo-rumen.

Intraruminal additions of water during eating did not affect the feed intake of cattle or sheep (Campling and Balch 1961), presumably because water rapidly leaves the rumen. These findings are important with regard to forage moisture content and its effect on dry matter intake.

Forage moisture level has been studied as a possible determinant of voluntary dry matter intake. Minson (1966), feeding either fresh or dried or frozen forage to sheep, showed no significant differences in voluntary intake resulting from method of preparation.

Renton and Forbes (1973) observed no significant differences in dry matter intake of barely supplement fed either as a liquid or dry supplement. Likewise, the supplement moisture level had no effect on intake of the hay being fed. Holmes and Lang (1963) concluded that dry matter intake of cattle feeding on fresh forage is not likely to be restricted by either a high internal water content in the forage or rain water on the leaf surface. Moisture level may affect selectivity of grazing. More succulent plants will usually be grazed in preference to drier, more mature plants. Jackson and Forbes (1970) observed that higher moisture levels in silage depressed voluntary dry matter intake in cattle. However, moisture levels may be having a secondary role to organic acids or other substances which are found in higher moisture silage and which may influence dry matter and intake in some manner.

Van Soest (1982) states intake is dependent on the structural volume and, therefore, cell wall content. The relationship between water content of forages and intake, therefore, may be a function of structural volume if the plant water is contained within the cell wall structure. The addition of water per se to the rumen has little effect upon intake because it is largely absorbed and removed. However, Van Soest (1982) believes water retention by the sponge effect of coarse structural components of ingested forage can have an inhibitory effect on intake.

Rate of disappearance of digesta from the reticulo-rumen depends primarily on its rate of digestion and this, in turn, depends on chemical and physical properties of the food consumed (Hungate 1966). The rapidly fermentable fraction of roughage does not occupy space in the reticulo-rumen for long periods of time, compared with structural components of roughage-cell wall fractions.

Presenting ruminants with roughage that is in a physical form which allows ready passage out of the reticulo-rumen is generally associated with a greater voluntary intake than when the same roughage is in a longer, coarser form (Minson 1963, Poppi et al. 1981a). These findings support the concept of physical limitation on roughage intake imposed by limited size of the reticulo-omasal orifice.

Waldo (1969) theorized that, with certain forages, intake could be limited by rumen capacity and rate at which undigested residues left the reticulo-rumen. Using this theory, Thorton and Minson (1972) postulated that voluntary intake could be estimated from rumen fill and rumen organic matter retention time. These researchers believed that if fill was assumed constant, dry matter intake and retention time would be inversely related. Thornton and Minson (1973) tested this hypothesis with grasses and legumes fed to sheep. They found a significant correlation ($r = -0.93$) between intake of digestible organic matter and retention time of organic matter in the rumen. It was concluded that, because rumen fill with all forages tested had been relatively constant, voluntary intake was primarily affected by retention time of the fibrous fraction in the rumen. Because retention time is reciprocal of rates of passage and digestion, the expression proposed is, in essence, intake = total outflow from the rumen. Greater consumption of leaf material versus stems in legumes (Hendricksen et al. 1981) and grasses (Poppi et al. 1981b) was associated with shorter retention time in the rumen and not by differences in digestibility as such. Poppi et al. (1981c) concluded higher voluntary intake and shorter rumen retention time of grass leaves over stems was associated with: (a) an apparent higher rate of digestion of neutral detergent fiber (NDF) in vivo, (b) higher rate of passage of the NDF from the rumen, and (c) higher potential digestibility of the leaf. Poppi et al. (1981b,c) found cattle had longer ruminal retention times for NDF and for large particles than did sheep. Golding (1976) concluded ruminal retention time of organic matter was theoretically a rational variable to predict voluntary intake, but more indirect methods to estimate rates of passage were needed.

It would appear variation in voluntary intake of forages over the gut-fill range could be explained to a high degree by differences in rumen retention time, independent of rumen fill. However, some inherent problems should be considered when interpreting this relationship. Rumen capacity can be affected by animal attributes such as pregnancy (Jordan et al. 1973). Thornton and Minson (1973) have suggested certain plant attributes, such as low protein content, result in reduced intake and gut fill. Under these circumstances, nitrogen deficiency would be the primary factor affecting intake. This point will be discussed in greater detail in a later section. Results of Egan (1970) point out that the level of reticulo-rumen fill is not constant between diets, but is influenced by other, presumably nutritional, factors. One such factor is protein nutrition of the animal. Campling (1966) noted, with roughages containing up to 8 to 10% crude protein, intake is apparently limited by reticulo-rumen capacity and rate of disappearance of ingesta from this organ whereas intake is limited by other metabolic factors with forages containing more than 10% crude protein.

Voluntary intake is also related to forage digestibility. Rate of passage through the reticulo-rumen has been shown to increase with increasing digestibility, even when rumen fill remains constant (Blaxter and Wilson 1962). Although voluntary intake increases with increasing digestibility, there is a point where further increases in food digestibility will result in zero or negative increase. Hutton (1963) noted a decline in voluntary intake of dairy cows grazing forage above 70% digestibility. The digestibility level above which energy intake remains static is not defined and varies between 56% (Montgomery and Baumgardt 1965a) and 67% (Conrad et al. 1964, Conrad 1966). A study by Dinius and Baumgardt (1970) showed little difference in voluntary intake when forage energy digestibility was expressed on a weight or volume basis. Dry matter intake increased as the digestible energy per gram increased to 2.5 kcal but, above this level, dry matter intake decreased and digestible energy intake remained static.

In a review, Conrad (1966) suggested forage intake is controlled by rate of passage up to about 66% digestibility but, above this level, other factors are involved. However, Minson (1971) observed large differences in voluntary intake which were related to digestibility, but had a different relation for many different forages (i.e., related to digestibility, but differed in intercept or slope). Montgomery and Baumgardt (1965b) indicated digestibility-gut fill controls may be influenced by particle size of forage fed. Other plant attributes, such as leaf-stem proportion, also affect the relationship. Laredo and Minson (1973) observed higher intakes of leaf fractions than stem portions, despite similar digestibilities.

Factors Affecting Intake

Major differences in nutritional regimes of grazing and housed ruminants have been described by McDonald (1968) and Osuji (1974). The type of food eaten will differ chemically and physically, e.g., in water content, proportions of leaf to stem, type and concentration of carbohydrates, and protein constituents. Food intake will not be to appetite in grazing ruminants if available food is difficult to harvest. It has been demonstrated that energy expenditure and the requirement for nutrients is markedly affected by the grazing animal's environment (Osuji 1974).

Body Size

Voluntary intake of grazing animals has been related to body size (Holmes et al. 1961) and to metabolic body size (Johnson et al. 1968). Energy demands are proportional to 0.75 power of body weight (Klieber 1961), thus, energy needs per unit weight of smaller animals are greater than that for larger ones. The rumen of young animals is relatively smaller than in adults, and their increased food requirement is usually met through increased appetite and faster turnover rate of ingesta (Hungate 1966). It may be that younger animals consume a higher quality forage, thereby causing a faster turnover rate. Arnold (1981) found 5-month-old sheep had a diet higher in digestibility and in nitrogen content, and lower in fiber, than that of older sheep. This may have been due to lambs being deliberately more selective when grazing, but it may simply be, that with smaller jaws, they can choose more precisely than older sheep. Similarly, Horn et al. (1979) found calves tended to select forage with higher crude protein level and lower acid detergent fiber (ADF) and cellulose levels than did cows. Waldo (1969) felt it was extremely important to express intake in relation to metabolic body weight.

When abundant, good quality forage is available, *ad libitum* intake of grazing ruminants is influenced by energy demand. Intake of cattle (Corbett et al. 1963) and sheep (Owen and Ingleton 1963) is related to liveweight, liveweight change and milk production.

For house sheep (Blaxter et al. 1961) and cattle Blaxter and Wilson (1962), *ad libitum* intake is proportional to metabolic size, but varies with feed digestibility. It is frequently assumed that intake by grazing animals also varies with some function of liveweight, but it seems unlikely any single relationship will be generally applicable because liveweight differences may result from differences in age, breed, and previous nutrition level (Langlands 1968). Langlands (1968) felt, within a breed, intake is more closely related to age than liveweight. It appears different classes of cattle do not have similar intakes, even when data are corrected for body weight.

Physiological Status

Changes in intake are largely determined by alteration in physiological requirements of the animal. Although dry, pregnant ewes within breeds have exhibited similar dry matter intakes, lactating ewes in the same flock required as much as 25 to 50% greater dry matter intake (Hutton 1963). Similar results were obtained in experiments utilizing dry vs. lactating sheep under grazing conditions (Arnold and Dudzinski 1967a,b). Likewise, Arnold (1970b) found greater digestible organic matter intake for pregnant and lactating ewes than for dry ewes. Dijkstra (1971) and Allison et al. (1981) found significant differences in average dry matter intake between lactating and dry, pregnant cows, with lactating animals consuming more than pregnant or dry cows and pregnant cows consuming more than dry cows. Rosiere et al. (1980) found dry 2-yr-old heifers consumed only 67% as much forage as lactating 2-yr olds. Journet and Remond (1976) also found similar variation in voluntary intake by cattle during lactation and pregnancy.

Body Condition

Intake is related to body condition as well as to body size. Body condition often varies more in grazing animals than in penned animals. In a grazing herd or flock, liveweights of mature animals vary over time, and body condition varies among individuals. Therefore, liveweight can be a poor index of energy demand and of intake, even when differences in productivity are accounted for (Arnold 1970a).

Arnold et al. (1964) noted that as thin sheep become fat, intake decreases, and intake and liveweight are negatively related. Langlands (1968) and Allden (1968) reported that thin sheep grazing with fat sheep make compensatory gain by increasing intake by 20% or more on a per unit of liveweight basis. Allden (1968) also found young sheep compensated for previous periods of undernutrition by eating more per unit liveweight than sheep which were previously well fed.

Supplementation

With the exception of Allden (1981), who reviewed work on the effect of energy and protein supplementation, most literature pertaining to supplementation has been confined to liveweight response. However, evidence is accumulating on the importance of supplemental protein and energy on voluntary intake of forages. Generally, it has been found that addition of readily available carbohydrates to a roughage diet decreases voluntary intake (Elliot 1967a, 1967b; Cook and Harris 1968; Rittenhouse et al. 1970; Lusby et al. 1967a, 1967b; Lake et al. 1974). Conversely, addition of protein supplements to low-quality roughage diets increases voluntary intake and digestibility (Elliot 1967a, 1967b; Cook and Harris 1968; Lyons et al. 1970; Kartchner 1980). Increases in intake associated with protein supplementation is generally attributed to increasing rumen microbial activity and consequently rate of passage. There is evidence that intake responses to protein supplementation occur only when forages contain less than 8 to 10% crude protein (Blaxter and Wilson 1963, Elliot and Topps 1963, Milford and Minson 1965), although Weston and Hogan (1968) and Rittenhouse et al. (1970) failed to show responses with forages of 6 to 8% crude protein.

Milford and Minson (1965) found forage intake by sheep declined precipitously when diet crude protein levels fell below 7%. However, intake and diet crude protein concentration were not well associated when diet crude protein concentration was above 7%. Apparently diet crude protein concentrations below 7% do not meet the nitrogen needs of rumen microbial populations (Van Soest 1982).

When pasture is sparse, provision of concentrations has less effect on forage intake than when pasture is readily available. Newton and Young (1974) reported substitution was greatest when herbage was abundant and least when pasture was sparse. (Conclusive research is lacking on the substitution of hay for pasture. However, hay wastage appears to be substantial when pasture forage is in good supply.)

Forage Preference

The degree of choice effect on intake has not been examined with grazing animals. In pens, Reid and Jung (1965) reported higher total hay intake when several hays were offered than when any one hay was fed alone. A similar effect might occur in grazing situations.

Strains of a species that differ in acceptability in a free choice situation, but have comparable digestibilities, may give different intakes when they are the sole feed. Comparisons of acceptable and unacceptable strains of *Phalaris arundinacea* have produced intake differences up to 36% in favor of acceptable strains (O'Donovan et al. 1967). These results do not show why intakes differed, but the authors implied odor was important. Arnold (1966) found, on 5 of 11 pastures, intake was influenced by either taste, smell or touch, with decreases in intake up to 61% and increases up to 35% due to sensory stimuli. Evidence is accumulating that acceptability of forage plants can strongly influence intake of grazing animals.

Experience can also affect intake. Intake of sheep inexperienced on pasture and in the environment may be depressed by 50% for as long as 10 months (Arnold 1970a).

Intakes of broadleafed plants can differ from those of grasses. Considerable research is available showing higher intakes for legumes than grasses when digestibilities are comparable (Ulyatt 1981). A review of forage class influences on intake of range ruminants is provided by Holechek and Vavra (1982). Leafy materials from forbs and shrubs usually have more rapid digestion rates than grasses at comparable stages of phenology (Short et al. 1974, Wofford and Holechek 1982). There is limited evidence that leafy materials from forbs and shrubs may have a faster passage rate than material from grasses (Milchunas et al. 1978).

Information is lacking on associative effects between forages on intake. However, associative digestibility may play an indirect role in increasing intake. For example, browse species in the diet may increase digestibility of grasses, increasing overall digestibility of the total diet with a corresponding increase in intake (Milchunas et al. 1978). During winter, shrubs with a higher crude protein content such as fourwing saltbush (Cordova and Wallace 1975) could improve the intake of grasses with crude protein levels below 7% by providing rumen microbes with a source of nitrogen.

Forage Availability

Arnold (1964), Arnold and Dudzinski (1966), Greenhalgh et al. (1966), and others have demonstrated that yield and physical presentation of available forage to grazing animals may have marked effects on feed intake under intensive pasture conditions, but may have no measurable effect on extensively managed pastures.

Even for pastures of a single plant species, there is rarely, over a short time span, a simple relationship between intake and pasture yield (Wheeler et al. 1963). The extent to which intake is kept below that determined by energy demand, and the chemical and physical attributes of the diet, depends on the adaptability of grazing behavior. A simplified model of intake, grazing behavior and pasture condition was presented by Arnold (1970a).

Homeostasis of intake with changing availability of forage is maintained by altering grazing time, bites per minute, and amount per bite. There is no set pattern of adjustment to meet a particular energy demand under different pasture conditions (Arnold 1970a), although relationships have been obtained between these variables and pasture yield in specific situations (Arnold and Dudzinski 1966). It is interesting to note that sheep with different energy demands (due to age, size or reproductive state) maintain the same intake differences over a wide range of pasture conditions (Arnold 1970a).

Allden and Whittaker (1970) defined herbage intake by an animal to be the product of eating rate and grazing time. These workers examined certain pasture attributes that determine ease of prehension of herbage. A close relationship was found betwen rate of intake and herbage availability. At herbage availabilities greater than 3,000 kg/ha, both grazing time and intake rate were relatively constant. As herbage dry matter decreased from 3,000 to 500 kg/ha, there was a four-fold reduction in the rate of consumption and a two-fold increase in time spent grazing. Allden and Whittaker (1970) speculated that, as amount of herbage decreases, a point is reached when herbage availability apparently imposes limitations on the rate at which animals can ingest feed, but this is compensated for by increased grazing time. Thereafter, animals extend their grazing period further, but compensation becomes progressively more incomplete, and total intake would be expected to fall drastically.

In work with dairy cattle grazing temperate pastures, Johnstone-Wallace and Kennedy (1944) observed consumption increases as herbage yield increased. Unlike Allden and Whittaker (1970), who showed the bite size of sheep increased linearly with increasing plant height or tiller length, Stobbs (1973a) found these factors did not exert a major influence upon bite size. Rather, sward bulk density (kg/ha/cm of herbage height) incorporating a low stem count and a high leaf/height ratio appeared to be the major factor affecting bite size of cattle.

Distribution of herbage in the canopy, particularly leaves, can influence the ease with which herbage is removed. Stobbs (1973a,b) found the ratio of sward leaf density and stem density in the uppermost layers of the sward had the highest correlation with bite size. These studies (Stobbs 1973a,b) emphasized that consideration of the sward as one dimension is inappropriate. Stobbs (1975) suggested that nitrogen fertilization of regrowth pastures increased bite size by presenting higher leaf yield to the animals.

Arnold and Dudzinski (1967b) studied the effect of herbage availability on intake of pregnant, dry and lactating ewes. These researchers found about 40% of the variability in digestible organic matter intake was accounted for by total dry matter available per acre.

Handl and Rittenhouse (1972), working with steers on crested wheatgrass pasture in eastern Oregon, found dry matter intake was not limited when herbage availability equalled or exceeded 135 kg/ha. In a later trial, dry matter intake was not limited at herbage production levels equal to or greater than 92 kg/ha or 176 kg/ha, using estimates of dry matter digestibility from clipped or dietary samples, respectively.

Conversely, many other workers have found high degrees of correlation between herbage availability and intake (Harkess et al. 1972, Langlands and Bennett 1973, Greenhalgh et al. 1966, Greenhalgh et al. 1967, Greenhalgh 1966, Marsh 1977). In strip-grazing experiments, Greenhalgh et al. (1967) allowed herbage to be available in amounts of 25, 35, and 45 pounds of dry matter per cow per day for a 3-month period. Higher allowances were not used because earlier experiments (Greenhalgh et al. 1966) indicated larger allowances were outside the critical range where herbage availability and intake were closely related. Herbage allowances of 25, 35, and 45 pounds of dry matter per cow per day resulted in mean intakes at 23.9, 25.6, and 26.4 pounds of organic matter per cow per day, respectively. These workers also noted the differences in digestibility between treatments were small.

Hull et al. (1961), using 700-pound steers grazing irrigated pastures, allowed 8 to 54 pounds of dry matter per head per day. Animals in this experiment ate all they were offered up to an allowance of 16 pounds of dry matter per day (of which they ate about 15 pounds), but consumed small proportions of further increment increases. Intake at a maximum allowance of 54 pounds per head per day was 16 pounds.

Broster et al. (1963) allowed 400-pound heifers to graze at three allowances: 2.67, 3.20, and 3.93 pounds of dry matter offered per 100 pounds of liveweight per day. In this experiment, intake increased linearly, the response being about 0.2 pound per 1 pound increment increase in amount offered. With the smallest allowance, 88% of the herbage was consumed and, with the largest, 64% was consumed.

Greenhalgh et al. (1966) stated the relationship between herbage consumption and herbage allowance is probably a curvilinear relationship. When less herbage is offered than animals consumed voluntarily, increment increases in herbage allowance are likely to produce increments of almost equal magnitude in herbage consumed. As allowance increases further, response is likely to become progressively smaller, and a point will be reached beyond which further increases have no effect on intake. Greenhalgh et al. (1966) emphasized that an increase in the allowance may affect quality as well as quantity of herbage consumed, because opportunities for selective grazing are increased.

Reardon (1977) allowed steers 10, 15, 22.5, and 33.8 kg dry matter per head per day, and dry matter intake was equated with dry matter disappearance in the standing crop. Results of this experiment ran contrary to those from other experiments, in that at a given level of herbage allowance, dry matter intake decreased with increasing pasture yield. This was attributed to confounding yield with plant maturity. However, it is also probably the result of the method used to estimate intake. Herbage disappearance is subject to many sources of bias. Among these are regrowth of grazed forage, trampling damage and weathering losses, as well as consumption by insects and rodents. Marsh (1977) studied dry matter allowances of 3.0, 4.5, 6.0, and 7.5 kg herbage dry matter per 100 kg liveweight using young, growing Friesian steers. Herbage intake per animal increased with increasing herbage allowance, but the rate of increase was lower in latter periods of the experiment, which coincided with both larger animal size and higher dry matter digestibility of selected forage.

Langlands and Bennett (1973) measured intake and nutritive value of the diet of sheep grazing at stocking rates ranging from 2.5 to 37.1 sheep/ha. Digestibility declined linearly with increasing stocking rate. Organic matter intake also declined linearly with stocking rate and increased asymptotically with herbage availability. Organic matter intake per hectare increased with increasing stocking rate, and maximum intake was predicted to occur at a stocking rate greater than that at which the sheep survived.

Using data from experiments conducted under diverse conditions and localities, Hart (1972) generated a model expressing the relationship between average daily gain of animals (ADG), forage production (F), and animal numbers (D) (expressed in animal days/ha). This worker stated that D/F was analogous to animals per unit area and F/D analogous to area per animal. The linear regression of ADG on F/D showed a sharp decline in ADG when F/D reached 20 kg forage per animal day. With decreasing amounts of forage per animal day. ADG continued to decline at an increasing rate. Although Hart (1972) monitored average daily gain instead of intake, it is highly probable intake also declines with increasing stocking rate.

Allison et al. (1982) created levels of grazing pressure of 10, 20, 40, and 50 kg forage available per animal-unt (au) per day for a 14-day period. Averaged over three trials, total forage disappearance values per animal-unit per day during a 14-day grazing period were 8.5, 12.0, 12.7, and 16.3 kg for 10, 20, 40, and 50 kg/au/day grazing pressures respectively. However, daily intake averaged across all treatments and trials was about 9 kg/au/day. At a grazing pressure level of 10 kg/au/day, forage disappearance approximated average daily intake, whereas grazing pressures of 20, 40, and 50 kg/au/day had forage disappearances that exceeded intake by 28, 48, and 90%, respectively. These data indicate a possibility for a two-fold increase in forage harvest efficiency by grazing cattle as grazing pressure is increased. Allison (1978) felt intake was depressed at forage allowances of 20 kg/au/day or less.

Grazing Systems

In a review, Herbel (1974) noted most studies have shown livestock production per animal is the same or lower for a rotation system compared to continuous grazing. Generally, there must be an improvement in range condition and, subsequently in carrying capacity, to justify a rotational scheme using livestock performance as a criterion (Herbel 1974). Grazing intensity reportedly affects animal performance. As a rule, with increasing grazing intensity, livestock have less chance to graze selectively because of increased removal rate of preferred species and plant parts. Bement (1969) reported daily gains of cattle on blue grama rangeland. As grazing intensity increased, total kilograms of beef produced per hectare increased, but individual animal gains decreased.

Bryant et al. (1970) summarized results of increased grazing pressure on animal and plant responses. Yield of herbage and weight gain per animal and per hectare were affected by grazing pressure. When grazing pressure was intense enough to limit availability of herbage, quality of grazed diets decreased. This was attributed to a reduction in opportunity for selective grazing. The coarser, more mature portions of plants were eaten, resulting in lower digestibility and nutrient content of the diet. Cook et al. (1953) and Pieper et al. (1959) also reported higher grazing intensities resulted in lowered diet quality in terms of nutrient content.

Vavra et al. (1973) studied chemical composition, intake, and gain of steers on two different grazing intensities, light and heavy. No great differences were observed between intensities for crude protein, gross energy, acid detergent fiber, lignin and cellulose levels in the diets. Heavy grazing resulted in somewhat lower values for dry matter digestibility and intake. Differences in intake were greater later in the season when total forage available may have become limited on the heavily grazed pasture. Individual livestock gains reflected the greater digestibility and intake observed on the light-use pasture. However, more gain per hectare was produced on the heavy-use pasture.

Blaser et al. (1973, 1974) pointed out that continuous grazing allows for greater forage selection by grazing animals. This is an important consideration when grazing warm-season grasses, which tend to lose quality rapidly with increasing maturity. These workers also noted low forage availability at the end of a rotation grazing period depresses gains and reduces total forage production.

Hart et al. (1976) found the average daily gain of steers was strongly and negatively correlated with grazing pressure, being lightest under continuous grazing and heavier under rotation and strip grazing.

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