BLOAT IN RUMINANTS AS A DYSFUNCTION OF ANIMAL AND PASTURE INTERACTION.

A consideration of the environmental and physiological factors associated with the condition, having particular reference to the grazing animal.

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P R O L O G U E.

It is a simple and yet fundamental biological concept that one of the essential differences between plants and animals lies in their mode of nutrition.

The plant is able to use soil nutrients and synthesize its nutritional requirements in the presence of light by the process of carbon assimilation. The animal is entirely dependent on these synthesized plant products for its nutrition.

In this very essential difference ruminants and herbage plants assume a commensal relationship, becoming increasingly interdependent as systems of pasture and animal production intensify.

This relationship has become a well accepted principle in herbage agronomy as to appear almost a statement of the obvious. Nevertheless the writer submits that progress in this field during the past two decades has been concerned almost solely with the botanical aspects of plant production.

The development of strains of plants for grazing conditions, with the additional benefits of an extended grazing season, and greater herbage bulk per acre, are achievements of the plant breeder which have been making an immeasurable contribution to animal production.

In spite of the ultimate use of herbage plants however, studies of the interaction of animal and plant have lagged behind the advances made by the plant breeder.

The animal has been used almost exclusively either as a measure of plant production in terms of liveweight increase, or as the controllable factor for the purpose of imposing particular environmental conditions upon individual plant species or communities. Bathe 1947 (1).

With this criticism in mind, Stapledon 1948 (2) discussing the subject of grassland management for animal production states that " the school to which I belong has been accused and not without a measure of justice, of paying insufficient attention to the needs of the animal. It is difficult to-day for any particular school of thought to march in step with all other schools-- but in proportion as knowledge accumulates, so does the need to do so become increasingly urgent. Plant nutrition is not just a matter of Ca, P, K, N, and animal nutrition involves much more than starch equivalent and protein equivalent."

Finally, Stapledon (2) reminds the agronomist that when he advises the farmer either by what he writes or what he says as to seeds mixtures and grassland management, in effect he wears the mantle of the nutritionist, for he prescribes the diet on which alone the animal may be fed for weeks or months on end.

Therein lies the trend of thought which has stimulated the subject of the discourse to follow.

The writer submits that any biological practice which is aimed at stimulating a preferred metabolic process will advance towards a state of imbalance in relation to other processes with an increasing intensity of stimulation.

Muir 1948 (3) subscribes to the widely held opinion that physiological disorders such as bloat, and grass tetany, are more common on leys than on permanent pasture. The difference claimed for the ley as against permanent pasture is one of relatively higher incidence of physiological disorders in animals pastured on leys, it being recognised that both types of pasture are capable at times of disturbing the physiological equilibrium of the grazing animal.

The implication is, therefore, that the temporary sward must tend to possess, at a high level of activity, the factors responsible for physiological aberrations in animals at pasture.

The principle of intensive grassland farming is not necessarily attacked but the present design of pastures under certain conditions of soil and management may be less able to provide a diet for health as well as productivity.

This is borne out by the many reports from those countries of intensive grassland production which indicate an increase in physiological disorders

arising from the imbalance of animal nutrition resulting from intensive pastoral management practices. (3). Bennetts 1946 (4). Filmer 1947 (5). and others. (14). (29).

The peculiar seasonal nature of these disorders, and the limitations of our knowledge in respect of seasonal changes in the chemistry of the growing plant, particularly in relation to the grazing animal, have resulted so far in but slow progress towards evolving measures of preventive treatment.

An awareness of the consequences which need to be anticipated from intensive grassland production in New Zealand is expressed by McMeekan, 1947 (86). He considers that it is more than a coincidence that such stock disorders seem to occur at periods of rapid change in pasture growth. McMeekan implicates changes from poverty to plenty, from high fibre to low fibre, from slow growing to rapid growing feed, and suggests that the need for adequate management techniques in this connection is an obvious line of attack.

An approach by means of perfecting our grazing management to overcome grazing disorders is suggested by Johnstone-Wallace 1950.(6), in referring to the bloat problem. At the same time he gives the opinion that the real solution lies perhaps as much with the agronomist and plant breeder as with the grazier.

The concept of breeding plants for bloat-proof pastures is entertained, and already recent literature refers to pasture seeds mixtures recommended for reducing the bloat risk. (33), (34), (35).

It is interesting to note that an agronomic approach, based on the use of pasture having a wider species composition is recommended to overcome a physiological disorder causing serious losses in sheep grazing subterranean clover in Australia. (4).

A new departure then becomes evident, as to those factors which are desirable in pastures and pasture plants. The writer subscribes to the view that the herbage agronomist will be aided in his approach to this new aspect of his work when possessed of an appreciation of the integral relationship between the plant and certain animal physiological processes.

For this reason an exposition of animal pasture interactions will be attempted using bloat in ruminants as the specific example.

Bloat in grazing ruminants is referred to by Johnstone- Wallace 1948 (7) as a problem arising more frequently with improved pasture production methods.

He suggests that it is perhaps the most important factor requiring investigation if a full utilization of improved pastures is to be obtained. McMeekan 1947 (86) states that it is a problem which emphasises the complexity of these animal-pasture interactions and considers that of all of them it is perhaps the most complex.

So far failure to produce the condition in the field has defied the more orthodox methods of experimentation. Any solution however rests more probably upon the integrated efforts of workers in allied rather than in any one field. The growing need for this type of approach in biological studies is keenly appreciated by the writer.

However, the opinion is supported that ultimately measures for the prevention of bloat will take an agronomic form. Further, the agrostologist should bring that thought to bear upon the problem which integrates those many aspects of his work designed to meet the needs of the animal.

An attempt will be made to follow that recommendation in this discourse. Should this dissertation provide also a reference base for constructive thought whatever manner of investigation is adopted for the bloat problem, its purpose will be well served.

Broadly the subject matter will be treated as follows:-

AA. The bloat problem, its manifestations and incidence.

BB.1. The in situ interactions of pasture and animal as phenomena associated with acute bloat. Part I - Plant-conditioned interactions.

BB.2. The in situ interactions of pasture and animal as phenomena associated with acute bloat. Part II - Animal-conditioned interactions.

CC. Ruminant digestion and bloat. The physiological processes involved, particularly as influenced by plant biochemical and physical factors.

AA. THE BLOAT PROBLEM. ITS MANIFESTATIONS AND INCIDENCE.

Bloat or hoven is a digestive disorder in ruminant animals to which cattle, sheep, and goats, are particularly subject. The condition arises from an abnormal distension of the rumen with gas. The essential symptom is a distension of the flank in the left lumbar triangle, although the whole abdomen may distend according to the severity of the condition.

It should be noted that bloat is a very common pathological conditon to which Begg 1912 (8) refers as the outstanding symptom of functional and organic diseased conditions.

Bloat is most frequently classified as "chronic" and "acute". In general, acute bloat usually depends upon the nature of the feed whereas chronic bloat is due to an abnormality in the physiological state of the animal. Cole, Huffman, Kleiber, Olson and Schalk 1945. (9).

Chronic bloat usually extends over a considerable period, such as that caused by obstruction of the oesophagus due to enlarged mediastinal lymph glands Ascott 1946 (10). or that associated with rumenal atony. Stuart and Cross 1946 (11).

Acute bloat usually refers to that condition which occurs within a few hours of pasturing; bloat in ruminants feeding green legumes is termed acute.

Dairy cattle grazing legume pastures in New Zealand have been reported to remain in a tympanic state for several months in certain seasons. Lyons. 1928 (12).

Nevertheless this discourse is primarily concerned with acute bloat as accepted in the general sense and manifest as a tympanic state resulting from abnormal feeding conditions, in particular as associated with pasturing legumes.

Mc Intosh 1941 (48) refers to two types of acute bloat--

a) in which gas is superimposed on the ruminal mass, its escape being impeded by obstruction in the oesophagus and

b) where gas remains admixed in the ruminal ingesta as noted after the engorgement with succulent food.

Whilst published experimental evidence is lacking of the relative susceptibility of the different ruminant species to acute bloat, McCandlish and O'Brien 1933 (13) report from a survey that dairy cows are more suscep-

tible than beef animals or sheep. Quin 1942 (14) suggests that dairy cows and lactating ewes are particularly susceptible owing to an incfeased appetite, and for the same reason Mead, Cole and Regan, 1944 (15) consider that lactating cows are more susceptible than dry cows. According to Bell and Britton 1939 (16) fat lambs are more susceptible than unfinished lambs on ladino clover pastures.

(a) BLOAT: A PROBLEM OF ANIMAL AND GRASSLAND HUSBANDRY.

Bloat in ruminants at pasture is a common disorder reported over a wide dispersal of countries such as New Zealand (12) Australia (42) South Africa (14) England (24) Scotland (13) France (30) Sweden (97) Germany (168) Canada (48) The United States of America (9) Spain (98) and the Argentine (87).

In all reports referred to, particular mention is made of the pasture composed either entirely of leguminous plants or as forming the bulk of the contained species.

Losses are reported in dairy and beef cattle, in mutton and wool sheep, whilst Berg 1950 (17) reports that milking goats are not excepted.

In Great Britain steps have been taken to implement a national survey to obtain field data on the bloat problem (88) (239) The economic importance of bloat, as with other disorders of grazing animals, is not apparent when losses and incidence only are considered.

Ward 1945 (18) indicates that wastage from bloat in dairy herds of the North Island of New Zealand amounts to an average of .22% of all cows, or 1.3% of animals culled annually during the period 1938-43.
Although the culling rate is comparatively low, it is the general experience that incidence is high particularly on individual farms characterised by clover-dominant pastures. Tyrer 1951 (20), (12), (93).
Losses recorded as due to bloat in the Massey College dairy herd in New Zealand, totalled 30 animals between 1940 and 1949. Although the actual milk production and management time losses are a matter of conjecture, they were none the less experienced. A general report of production losses in New Zealand was received from Johnson (personal communication). Referring to the Kairanga area this observer reports that throughout the district bloat causes an appreciable loss in production in individual herds, and causes the dairy farmers and occasionally the sheep farmer some concern. The incidence of bloat in dairy herds during the spring

months of 1949 was instanced as being so severe in some areas that production fell rapidly, and paddocks carrying what should have been ideal pasture for dairy stock were barred from grazing.

There is a paucity of information in the literature concerning milk production losses from bloat, but such losses are in evidence. In England, Wooldridge 1947 (21) refers to the lowering of milk production in individual cows for several weeks after recovery from bloat. In one dairy herd in England known to the writer, total milk yields dropped from a daily average of 200 gallons before the severe outbreak of acute bloat to 110 gallons daily average immediately after and in the ten days following the attack. Longman (personal communication).

Cole et al. (9) comment on the fact that very few surveys of the losses attributable to bloat have been made. They quote Welch, Marsh, and Tuncliffe. 1929 (22) who state that on the basis of a survey in Montana, cattlemen may expect a loss from bloat on sweet clover pasture of less than 1 per cent, and sheepmem about 0.5 per cent.

Mc Candlish (13) reports bloat on 34 per cent of the dairy farms in the South West of Scotland, this figure being obtained in replies from 152 livestock producers.

Hanson and Boyd 1943 (23). made a survey of 1,106 herds with nearly 30 000 head of cattle in Minnesota. A total of 11,205 head were pastured on sweet clover and alfalfa in approximately equal numbers. From May to October 182 cases of bloat were reported, and of these 50 were fatal. Alfalfa caused 28 deaths, sweet clover 20. Six cases of non fatal bloat were reported on non-legume pasture.

In California, Bell and Britton (16) made a survey over seven weeks during July and August of losses on ladino clover pasture. These observations were confined to six ranches with a livestock population of 47,000 lambs and 3,200 cattle. Twenty lambs, representing about 50 per cent of the total losses during the period, died of bloat. Two steers died from this cause,more deaths from bloat occurred in pastures with a stand of pure clover, or with a very high percentage of clover, and bloat was not a problem in certain pastures covered with more than 50 per cent grasses. Bathe 1948 (24) investigated the occurrence of bloat over 53 dairy farms totalling 1,160 animals, in the South West of England during the spring and summer months of 1944 and 1945. Losses amounted to only 3 and 4 cows respectively in each year, but animal and pasture management

practices were seriously hampered by the incidence and risk of bloat.

There are a number of reports which indicate the incidence of bloat occurring in particular districts associated with environmental conditions conducive to rapid and lush herbage growth. (24), (13). In New Zealand, Hawkes Bay, Bay of Plenty, and Manawatu districts are known as particularly troublesome areas, (19), (18), (93). Similarly, irrigated pasture areas especially where lucerne is cultivated are known to stimulate pasturing conditions conducive to bloat. Cole, Mead, and Regan 1943 (25), Beruldsen and Morgan 1936 (26).

It is in the various management aspects of pasturing animals that the most serious inconvenience can result when acute bloat occurs. Due to its insidious nature it is difficult to predict the onset of bloat. Quin 1943 (27), whilst according to Ferguson 1950 (28), there is no way except by grazing to tell if a pasture will cause bloat. This uncertainty necessitates constant vigilance of animals at pasture which wholly uneconomic practice is reported by McIntosh 1937 (29), to be responsible for some stockowners selling their herds due to bloat trouble. In South Africa, Quin (14), refers to the fact that stockowners are compelled to use lucerne in hay form with resultant nutritive losses and increased production costs.

The risk of bloat on lucerne pastures in France is a particular hazard to night grazing. Davis 1950 (30). This will be appreciated when it is realised that such pastures are usually unfenced and free grazing is practised. Similar difficulties will be expected to prevail when cattle are extensively grazed in ranching countries. (86).

The feeding of hay to animals prior to grazing pastures on which there is a bloat risk is a preventive measure generally recommended. Olson 1940 (31), and practiced Candy 1947 (32). Apart from being uneconomic, particularly under all pasture systems of farming, there is no conclusive evidence that such a practice is effective, although it has been claimed on the basis of experimental findings that feeding hay will reduce bloat. (25

Recommendations are made for the compilation of seeds mixtures in which legume species are reduced or excluded to lessen the risk of bloat Butler 1949 (33), Jones, Burle and Brown 1942 (34), Mead, Britton and Cole. Generally the inclusion of a greater percentage of grass species

is recommended; This is an entirely empirical agronomic approach for which there is a need to investigate experimentally. Legume pasture plants are usually implicated in the etiology of bloat, and it is reported that bloat will not occur or is reduced on pasture in which grass species are over 50 per cent dominant (16).

This is not the experience of the writer who has observed under New Zealand conditions the onset of bloat in dairy cows severely rationed on pasture containing over 80 per cent grass species.

Reports from dairymen in England indicate that severe bloat incidence with fatalities has occurred on pasture with cocksfoot dominant, Young 1947 (36), Shook 1947 (37).

The exclusion of legumes from pastures would be a practice detrimental both to herbage production and soil fertility, and is a recommendation to be questioned, on the basis of present knowledge concerning the incidence of bloat.

A number of observers report the incidence of bloat as being high during flushes of clover growth in pastures (12), (13), (14), (22), (44). Pasture management to maintain a balance between grass and legume species is considered to reduce bloat risk (93). But even under constant weather conditions, this requires such highly skilled grazing management, often at difference with animal production, as to throw doubt on its economic value under farm conditions.

Measures have been adopted for dairy cow grazing to restrict pasture available at a herbage growth stage when bloat is anticipated (19) and Adams 1950 (38), for which some success is claimed. The system of rationed grazing to prevent bloat remains to be proved however, and its effects on animal production, and pasture composition need to be assessed before this system can be confidently recommended for general practice. Its adoption is strictly limited to intensive systems of pasture and management.

(b) FEED AND ENVIRONMENTAL CONDITIONS ASSOCIATED WITH BLOAT.

According to Muir (3) it is evident that bowel inhibitory substances in forage plants reach threshold levels for the appearance of clinical symptoms only under certain conditions of soil, weather, stage of growth, and botanical composition of pasture. Accordingly intensive study of these factors is considered even more necessary for the prevention of

bloat than the identification of the toxic agents which may be involved. It is important then to be familiar with the feed and environmental conditions under which bloat occurs.

Cattle and sheep at pasture were reported to suffer from bloat over eight decades ago. Large 1863 (99). Acute bloat did not become a serious problem according to Niborg 1795 (39), until the middle of the eighteenth century when the pasturing of clover and lucerne became a common practice. The condition is now known as a common sequel to grazing on clover or other leguminous crops when it is often termed "clover blown" Phillipson 1942 (40). The following leguminous crops have been reported as promoting bloat: lucerne (25) white clover (26) red clover (13) ladino clover (16) sweet clover (44) peas (42) and trefoil. (90)

Other green feeds are known to give rise to bloat; the writer has observed bloat in dairy cattle feeding Kale, grass lawn trimmings in which legume species were absent, pasture comprised of over 80 per cent grass species, and in sheep grazing rape, turnip tops, growing wheat and barley. Shanks 1946 (41) states that bloat may occur in sheep during the winter if they have access to the green cereals wheat and barley; rapidly growing green cereals are reported by Ohman 1938 (42) in Australia to cause bloat in cattle. In the same country Veech 1937 (43) refers to travelling cattle becoming blown when excess green feed is available, such as variegated thistle and the leaves of the Kurrajong and willow trees.

The rate and stage of growth at which herbage plants are pastured is reported widely as being an important contributory factor in the onset of bloat. Cole.et. al. (25) claim to produce bloat on lucerne pasture in any season of the year and under varying environmental conditions provided the pasture is in the pre-bloom stage of growth, succulent, and thick enough to allow for rapid ingestion.

Kephart 1929 (44) surveying the occurrence of bloat on sweet clover concluded that incidence was highest when the clover was succulent.

Rapid, succulent growth of sufficient quantity would seem to be the general pasture conditions for inducing bloat. Dixon 1938 (45), 1939 (46) and others (41), (42), (35), (13).

Reference to particular parts of the plant is made by Quin (27) who states that bloat in sheep was associated with the ravenous consumption of the green leafy tops of lucerne. In this connection it is worth noting

a dairyman's observation on dairy cows grazing a dominantly cocksfoot pasture on which severe attacks of acute bloat were experienced: "the cattle were curling their tongues around the top of the cocksfoot (which included the flower). The tug then given to sever each mouthful caused the cocksfoot stem to break off some way below, with the result that the unbleached centre stalk was pulled out of its sheath, and this was consumed as well as that which the cattle had already taken into their mouths". Young (36).

The stall feeding of lucerne tops has induced severe bloat in cattle (15) although lucerne tops sampled from the same pasture at the same time and fed in the same dry matter proportions did not cause bloat. The writer under New Zealand conditions has induced bloat in two dairy cows by cutting and feeding random samples from a pasture of mixed grass and clover species, on which bloat regularly occurred. In this manner it is possible to determine the amounts of pasture consumed causing the onset of bloat. Similarly more controlled studies regarding the time interval to the onset of the condition can be made, as well as certain reactions of the rumen motility cycles.

The feeding of cattle on grain alone is reported as causing bloat, Mead and Goss 1935 (47). In this case continuous feeding on the same ration gave rise to the condition which could not be considered the same as acute bloat arising from legume pasturing.

Where soil conditions are conducive to lush pasture growth the risk of bloat is generally considered to be increased (20) (13) and it is not uncommon for the top dressing of pastures to be implicated (8) (93). In this respect McIntosh 1941(48) in Canada makes the contrary statement that bloat is less frequently encountered on lucerne pastures where fertilisation and irrigation have been well maintained, than is the case on neglected pastures growing on poor soil. This is not in accord with the report of Beruldsen and Morgan (26) in Australia who instance bloat as one of the problems associated with lush clover growth under irrigated conditions. Similarly Cole et al (25) state that irrigation of lucerne is necessary to promote the succulent growth conducive to the experimental production of bloat. Alway 1927 (49) reports a wide variation in the Sulphur content of legumes depending upon the sulphur content of the soil.
Doak 1929 (100) in New Zealand has found that the sulphur content of lucerne is decidedly increased in many cases by soil treatment with sulphur or

Sulphur compounds. He found that untreated lucerne on analysis showed a range in sulphur of 0.26 per cent to 0.3 per cent. The lucerne leaves contained a higher percentage of sulphur than the stems. To what extent soil factors affect the chemical composition of the plant subsequently influencing the level of hydrogen sulphide gas production in the rumen is a matter for conjecture at our present state of knowledge.

Weather factors no doubt have a very important if somewhat indirect influence on bloat by affecting those pasture conditions associated with a high incidence. Rainfall and temperature variations may have the following primary effects on a pasture.

a) Increases quantity of herbage per acre.

b) Conditions palatability of the herbage.

c) Influences the dominant production of any one or group of herbage species in a pasture.

Superimposed on and accentuating the influences of c) will be those influences resulting from the defoliation effected by the grazing animal.

It will follow that those quantitative etiological factors in bloat will operate as a) and b) reach optimum conditions in respect of the grazing animal. The qualitative factors will be determined by the nature of the species dominance in c) all other factors being equal.

This temperature, rainfall, and pasture growth relationship as it may be contributory to the incidence of bloat will be developed further in the following section.

At this stage it is pertinent to note that Cole et al (25) claim to produce bloat at will in any season on lucerne pastures where plant water requirements are under control by irrigation. Bathe (24) in England reports that weather favouring bursts of succulent non fibrous herbage seems liable to cause risk of bloat during the seasons of optimum plant growth. High rainfall effecting excessive growth of sweet clover in Iowa was considered by Pammel 1930 (50) to give rise to an unusually high incidence of bloat.

This role of humidity as it may effect bloat in grazing animals is far from being understood. The writer submits however that severe bloat in dairy cattle rarely occurs in much less than one hour after pasturing provided they have not been pre fed on a bloat provoking feed. This is in accord with the findings of Cole et al (25) and referred to by others. (6), (51). In view of this fact it is not unreasonable to assume that

primarily a herbage quantitative factor operates to promote the onset of acute bloat whatever the subsequent qualitative reaction. Given this assumption, plant palatability insofar as it influences herbage consumption is an important factor for consideration. The role of humidity then may be implicated in its influence upon plant palatability at those times when risk of bloat incidence is high.

Already the complexity of those interactions involved in the bloat problem become apparent, hence brief recapitulation will lend perspective to further development of the subject.

a) It is evident that acute bloat as a problem of grazing ruminants is world wide.

b) Economic losses from bloat whilst difficult to measure are in evidence from the many reports cited. Such losses are primarily concerned with bloat as a managerial problem.

c) The legume species of herbage plants are those most strongly implicated as inducing bloat in grazing animals. It is not uncommon for other green fodder plants to give rise to the condition.

d) That development stage attained by herbage plants which presents conditions for optimum consumption by the animal is implicated in acute bloat.

Under conditions of active growth, that stage of plant development will be expected to fluctuate according to variations in natural and induced environment.

It will be noted that this section has been concerned with the more general aspects of bloat in ruminants. This approach has enabled the resolving of scattered information into the above generalisations. A more particular examination of the questions posed in c) and d) will follow.