Onderstepoort Journal of Veterinary Research,
Volume 26, *Number* 2, *November,* 1953.

The Government Printer, Pretoria.

THE SIGNIFICANCE OF REFLEX SALIVATION IN RELATION TO FROTH FORMATION AND ACUTE BLOAT IN RUMINANTS.

K. E. WEISS, Onderstepoort Laboratory.

The successful use of surface tension agents in the treatment of acute bloat, [Clark (1950) and Quin, Austin and Rattcliff (1949)] has confirmed the importance of frothiness of ruminal ingesta in this condition, a subject of much controversy in the past. In their discussion on frothy bloat Cole, Huffman, Kleiber, Olson and Schalk (1945) do not appear to be convinced of its significance. Various workers [Wester (1935), McCandlish (1937), Dougherty (1942), Olson (1942), Quin (1943) and Clark (1948)] on the other hand, have reported the existence of frothy ruminal ingesta in cases of bloat on green legumes. Kick, Gerlaugh and Schalk (1937) also believe that frothiness is the factor responsible for bloat in cattle fed corn in the feed lot.

McCandlish (1937) supported by Olson (1942) and Quin (1943) incriminated saponins in lucerne as being responsible for frothing. It is difficult however to explain all the manifestations of acute frothy bloat on the basis of the saponin theory, with the result that the pathogenesis of this condition has remained unsettled.

Clark and Weiss (in press) have recently demonstrated the existence of a salivary reflex initiated by mechanical stimulation of the mucous membrane of the fore-stomachs. The object of this paper is to indicate the significance of this reflex in relation to froth formation and bloat.

METHOD.

Each of six Merino sheep with permanent ruminal fistulae were given 4,000 grams freshly cut green lucerne daily and the following data were collected over the experimental period:—The consistency of the ruminal ingesta of each sheep before feeding; the degree of bloat, and the type and consistency of the ruminal ingesta two hours after feeding. The type of lucerne fed daily and its origin were also noted.

For the determination of consistency the apparatus depicted in Fig. I was used. This consists of a mercury filled glass bulb (A), weighing 15·9 grams, attached to a thin rod. A silk thread connects the rod with the scale pan (B) onto which a pointer arm is attached. The thread is passed over two pulleys on a crossbar which is fixed to an ordinary retort stand. A 200 c.c. test tube (C) is clamped into position to receive the glass bulb.

With the bulb at the bottom of the test tube and the pointer arm opposite a zero mark (D), the tube is filled with ruminal ingesta. Sufficient weights are then placed on the scale pan to cause the bulb to be drawn through the column of ingesta, the fixed distance of 18·7 cm. (D to E) in approximately 3 seconds. The consistency index is then obtained by multiplying the weight required by the actual time taken.

Received for publication on 6th December, 1952.—Editor.

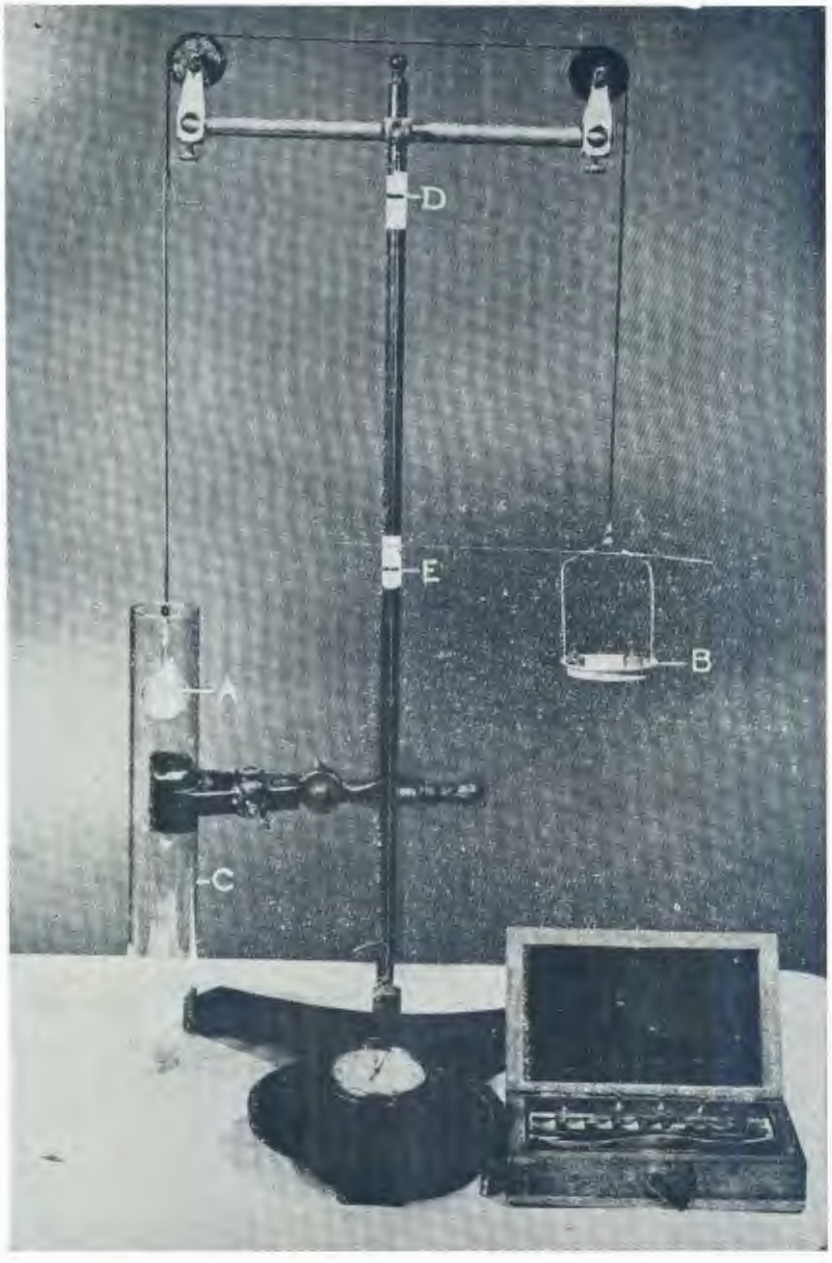


FIG. 1.—Apparatus used for the determination of consistency.

RESULTS.

1. *The relation between consistency of ruminal ingesta and the occurrence of frothiness and bloat.*

The ruminal ingesta of sheep fed exclusively on green lucerne has a tendency to foam, but the type of foam formed was found to be directly dependent on the consistency of the ingesta. When the ruminal contents were watery the gas-bubbles rose freely to the surface to form a layer of unstable free foam on the top. As the consistency increased there was a greater tendency for the gasbubbles to become entrapped in the thick viscid material, causing the ingesta to rise up into a frothy mass.

The data on one of the sheep collected over a period of 19 days are given in table 1. Similar results were obtained from the other experimental animals. A summary of the results is given in table 2. The degree of bloat was rated arbitrarily but it should be mentioned that it is extremely difficult to determine the exact degree of bloat in sheep with fistulae as some leakage of gas invariably takes place. Under normal circumstances the degree of bloat would have been much greater than that actually encountered.

TABLE 1.

The relation between consistency of ruminal ingesta and the occurrence of frothy bloat as determined by the physical condition of green lucerne.
(Details of one Individual Sheep.)

Type of Lucerne.	Days.	Before Feeding.	After Feeding.		
		Consistency Index.	Consistency Index.	Type of Ingesta.	Degree of Bloat.
Flowering stalky small leaves	1	21·6	7·2	Watery with small amount of free foam on top	Nil.
	2	31·2	7·5		Nil.
	3	30·8	5·2		Nil.
	4	45·0	7·8		Nil.
	5	35·2	6·0		Nil.
	6	—	9·3		Nil.
	7	24·0	9·0		Nil.
Crisp, succulent pre-bloom large leaves	8	50·0	33·6	—	Severe.
	9	38·4	50·0	Large amount of intermixed, tenacious froth.	Marked.
	10	62·5	39·1		Marked.
	11	45·0	66·0	—	Marked.
	12	45·0	15·0	Watery with free foam on top	Nil.
	13	70·0	45·0	—	Marked.
	14	38·5	60·0	Large amount of intermixed tenacious froth	Marked.
	15	70·0	75·0		Marked.
	16	60·0	69·0		Marked.
Stalky, etc.....	17	75·0	10·0	Watery with free foam on top	Nil.
Crisp, succulent, etc....	18	66·0	45·0	Large amount of intermixed tenacious froth	Marked.
	19	36·0	90·0		Marked.

TABLE 2.

The relation between consistency of ruminal ingesta and the occurrence of frothy bloat as determined by the physical condition of green lucerne.
(*Summary of results.*)

Days.	Type of Lucerne.	Number of Sheep Used.	Number of Sheep showing Frothy Bloat.	Average Consistency of Ingesta.		
				Before Feeding.	Two Hours after Feeding.	
					Bloated Sheep.	Non-bloated Sheep.
1	Flowering stage, stalky with small sparse leaves. Old hard stems present	6	0	46·3	—	7·3
2		6	0	43	—	7·6
3		6	0	44·1	—	5·7
4		6	0	50·3	—	8·2
5		5	0	37·4	—	8·2
6		5	0	38·8	—	7·6
7		4	0	42	—	14·3
8	Preflowering stage crisp succulent with large leaves, old dry stems absent	6	5	68	63·9	9·0
9		6	5	36·6	92·8	14·0
10		6	4	50	63·8	14·8
11		6	5	67·5	119·8	12·5
12		6	4	67·3	50·2	16·5
13		6	5	64·3	80·4	12·5
14		6	5	43·5	55·1	13·0
15		6	6	94·6	97·6	—
16		6	6	66·8	68·8	—
17	Stalky, etc.....	6	0	59	—	12·1
18	Succulent, etc.....	3	3	87·1	47·5	—

These results clearly show that whenever the ruminal ingesta was thick and viscid with a high consistency index after feeding, frothing was marked and bloat occurred. Animals with a watery ingesta and a low consistency index did not bloat.

To show how frothing of ruminal ingesta with a high consistency index interferes mechanically with eructation, air was introduced artificially into the rumen of one sheep by the method described by Weiss (in press). In order to ascertain whether eructation could take place normally, air was first introduced above the ruminal mass by passing the air inlet only just through the fistula stopper. The air inlet was then pushed deeply into the ruminal contents and air again introduced at the same rate. This procedure was followed in the same sheep when the ingesta had a consistency index of 42 and again 2 hours after feeding when the ingesta was reduced to a watery consistency with an index of 9.

The tracings reproduced in fig. 2 show the results. With the ingesta viscid and thick, tracing A shows that free air can be eructated efficiently, but when the air was bubbled through the ruminal mass there was marked interference with eructation as shown in tracing B. This was undoubtedly due to the ingesta rising up into a frothy mass which has the same effect as overfilling of the rumen by

mechanically interfering with eructation [Weiss (in press)]. On the other hand tracings C and D show that no such interference with eructation took place when air was bubbled through watery ingesta.

2. *Variations in consistency of ruminal ingesta and the effect of the type of lucerne.*

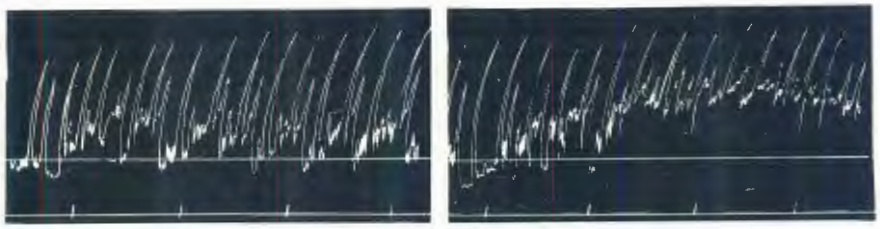
Clark and Weiss (in press) have recently demonstrated a salivary reflex in sheep and goats initiated by mechanical stimulation of the cardiac region of the forestomachs, causing a four-to-five-fold increase in salivary flow.

It is evident from the data in tables 1 and 2 that the ruminal ingesta of the sheep on green lucerne showed marked variations before and after feeding. The ingesta invariably had a high consistency index before feeding. This may be explained by the absence of sufficient coarse material in the rumen to stimulate a continuous reflex salivary secretion.

FIG. 2

THE EFFECT OF CONSISTENCY OF THE RUMINAL INGESTA ON GAS RETENTION

I: Ruminal Ingesta 'thick' and 'glutinous'. Consistency Index 42.



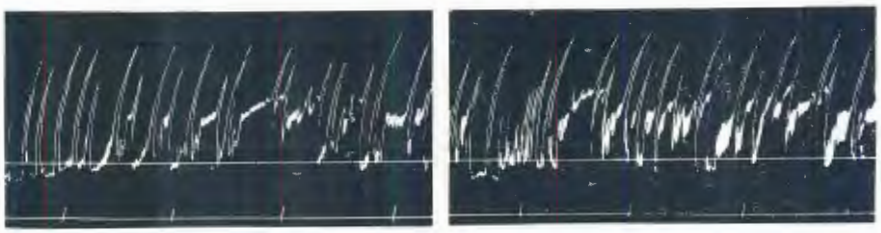
Normal eructation of free air introduced above the ruminal mass.

A

Interference with eructation due to retention of air introduced deeply into the ruminal mass.

B

II: Ruminal Ingesta watery. Consistency Index 9.



Normal eructation of free air introduced above the ruminal mass.

C

Normal eructation due to free escape of air introduced deeply into the ruminal mass.

D

The consistency of the ruminal ingesta and the occurrence of frothy bloat after feeding was shown to be influenced by the type of lucerne fed. It was found that bloat, caused by frothing of thick, viscid, ruminal ingesta, occurred immediately on feeding succulent, leafy lucerne in the preflowering stage of growth. When mature stalky lucerne was fed, the ruminal ingesta immediately reverted to a watery consistency even in the absence of available drinking water and bloat ceased. The conclusion is justified that the rapid reduction in consistency of the ruminal ingesta after feeding stalky lucerne was due to reflex stimulation of salivary

secretion initiated in the forestomachs by the physical character of the feed. It was also noted that ingestion of this type of lucerne was slow, with the result that proportionately more saliva is secreted per given weight of food.

The occurrence of bloat on the succulent lucerne is ascribed to the lack of coarse material and consequent diminished reflex salivary secretion. The rapid rate of feeding observed in the case of this type of lucerne contributed by causing a proportionately smaller amount of saliva to be secreted per given weight of feed. The consistency of the ruminal ingesta therefore increased and, if gas-formation was adequate, the ingesta rose up into a tenacious frothy mass.

In order to prove further that the presence of coarse material in the rumen is the main stimulus for the copious salivary secretion encountered, 120 grams chopped grass hay was introduced directly through the fistula into the rumen of one sheep. The consistency index of the ingesta before introduction was 150; one hour later it was reduced to 12 despite the absence of drinking water. This proved undoubtedly that the reflex is far more important in controlling the consistency of the ruminal contents than reflexes initiated by the sense of taste or the acts of chewing and swallowing.

Cole, Mead and Regan (1943) showed that bloat could be prevented by feeding coarse hay prior to lucerne pasturing. It was therefore decided to determine whether this protective action is due to reflex stimulation of salivary secretion. The sheep were divided into two groups of three each and fed succulent green lucerne. Each animal in group I received in addition 400 grams chopped grass hay well mixed with the lucerne. The results are given in table 3.

TABLE 3.

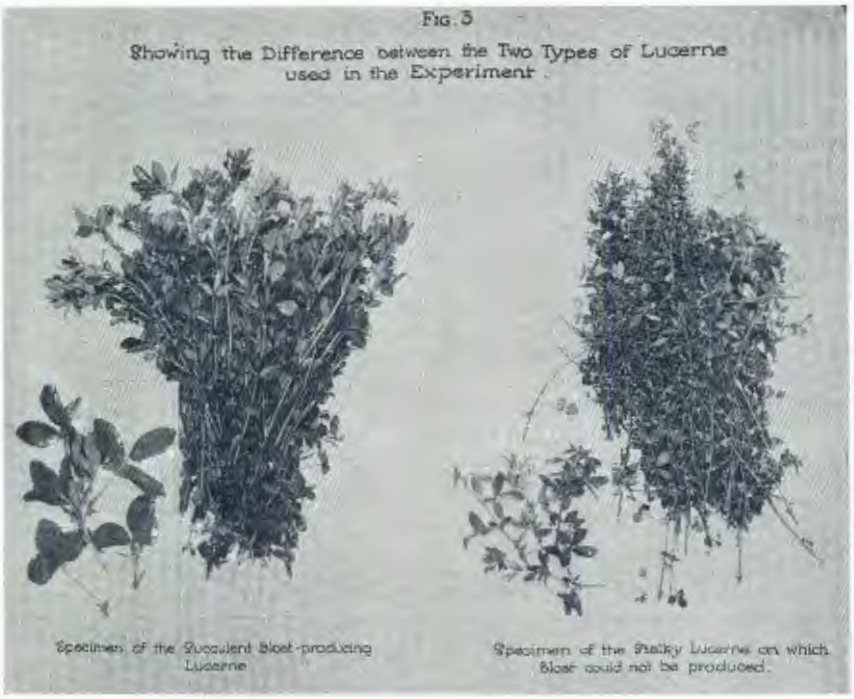
Days.	*Group* 1: 3 Sheep Fed Succulent Lucerne 400 grams Grass Hay mixed.			*Group* 2: 3 Sheep Fed Succulent Lucerne only.		
	Average Consistency Index of Ruminal Ingesta.		Number of Sheep showing Frothy Bloat.	Average Consistency Index of Ruminal Ingesta.		Number of Sheep showing Frothy Bloat.
	Before Feeding.	2 Hours after Feeding.		Before Feeding.	2 Hours after Feeding.	
1.....	65·8	10·5	Nil	74·5	47·5	3
2.....	31·8	9·0	Nil	52·5	48·0	3
3.....	30·0	15·0	Nil	46·8	32·0	3

It can be seen that bloat did not occur in those sheep receiving grass hay in addition to lucerne and that the consistency index of their ruminal ingesta was low compared to the group receiving succulent lucerne only. In the latter group bloat occurred daily. In another experiment the sheep were given a choice of succulent lucerne and grass hay. This practice, however, did not prevent bloat completely as the sheep did not eat any hay until a certain degree of bloat had developed. The consistency of ingesta was reduced and the bloat subsided within an hour of the animal taking the hay. As soon as distention of the rumen took

place, the sheep refused to take further lucerne and showed preference for the coarse hay. This indicates a natural tendency to supply the roughage required to maintain reflex salivation and prevent bloat.

An example of the marked difference between the two types of lucerne used during the experiment is shown in fig. 3.

FIG. 3.



A B

A specimen of the bloat-provoking lucerne is shown on the left. This was in the preflowering stage, approximately 18″ high and exceptionally succulent and crisp with large closely packed leaves. Contaminating weeds and old dry stems were absent. B shows a specimen of the lucerne on which bloat could not be produced. This was in the flowering stage approximately 12″ to 15″ high and stalky with small sparse leaves. A fair amount of old hard dry stems were present. A noteworthy fact is that the succulent lucerne grew on heavy black soil, which retains moisture well. The stalky lucerne grew on light sandy loam which is well drained. Both lands were irrigated regularly. It appears to be quite obvious that these factors influence the growth of lucerne and directly determine its bloat-provoking potentiality.

DISCUSSION AND CONCLUSIONS.

The experimental results clearly show that frothing of ruminal ingesta is the main cause of bloat in sheep on green lucerne, acting in the same manner as overfilling of the rumen, by mechanically interfering with eructation [Weiss (in

press)]. Cole *et al,* [cited by Cole, Huffman, Kleiber, Olson and Schalk (1945)] however, claim that they have tapped a number of cows bloated on lucerne pasture without encountering a single case in which the free air space was absent. Taking these observations into account, Cole *et al.* (1945) find it difficult to understand how frothing could cause bloat when a free air space exists. In the present author's opinion it is merely a matter of degree of frothing. In most of the cases of frothy bloat produced during the experiment, free gas escaped from the fistulae on opening. Only in a few cases did the ingesta froth to such an extent as to fill the whole rumen and exude from the fistula on removal of the stopper.

Cole, Mead and Regan (1943) have shown conclusively that the feeding of coarse hay prior to lucerne pasturing prevents bloat; and the experiments of Mead, Cole and Regan (1944) proved that the incidence of bloat was much higher in cattle fed ground hay and grain than in those fed unground hay and grain. These workers attributed the protective action of hay to their theory that coarse material is necessary to elicit the eructation reflex. The present author has shown previously [Weiss (in Press)] that the physical state of the ruminal contents does not appear to affect the eructation reflex directly. The results now obtained clearly show that the protective action of hay is due to reflex stimulation of salivary secretion, thus reducing the consistency of the ruminal ingesta and obviating froth-formation. The cases of bloat in cattle on a non-roughage diet, which has been reported by Mead and Goss (1936) can also be explained on the same basis.

Perhaps the greatest single factor responsible for the failure to elucidate the pathogenesis of bloat has been the difficulty encountered in reproducing the natural condition. Cole, Mead and Regan (1943) however, showed that certain essential conditions are necessary before bloat can be expected to occur. These are briefly summarized as follows:—

(1) The lucerne should be in an appropriate stage of development e.g. crisp and succulent to allow for rapid feeding.

(2) Animals should be deprived of all hay and straw and the lucerne itself should be free of grasses, weeds and old dry tough stems.

(3) The lucerne should have been provided with sufficient water to induce rapid growth.

(4) The greenfeed should be fed as fresh as possible and should not be older than 24 hours. Dried alfalfa tops failed to produce bloat.

These observations are confirmed by the experimental results recorded above. Contrary to the interpretation of those authors however, who ascribe the bloat-provoking capacity of this type of lucerne to a lack of sufficient coarse material to initiate the eructation reflex, it is maintained that the physical condition of the lucerne has a direct bearing on the occurrence of bloat through its action on reflex salivation. The rate of feeding of succulent lucerne appears to be an important factor. In accordance with reports by other workers [Mead *et al.* (1944)] the occurrence of bloat could not be correlated directly with the amount of lucerne consumed. In many cases of bloat in these trials the amount of lucerne eaten was actually less than that consumed by non-bloated sheep. A difference in the rate of feeding of the two types of lucerne was however noted. The amount of succulent lucerne consumed over a given period of time was much greater than the amount of stalky lucerne over the same period.

In the present author's opinion the presence of saponins in lucerne is also not the cause of bloat *per se,* but it merely contributes towards the colloidal state

of the ingesta favourable for foaming. Daily mechanical shaking of samples of expressed lucerne juice over a period of months under different meteorological conditions showed no significant variations in the amount of foam produced daily.

SUMMARY.

(1) Frothing of ruminal ingesta is the main cause of bloat in sheep on green lucerne.

(2) It was found that the formation of froth is dependent on the consistency of the ruminal ingesta which in turn is influenced by reflex salivary secretion.

(3) Reflex salivary secretion is largely stimulated by the presence of coarse material in the forestomachs and the amount of saliva secreted, therefore, depends on the physical condition of the feed. The explanation for the protective action of hay is based on this finding.

(4) The condition and type of lucerne fed has a direct bearing on the occurrence of bloat.

ACKNOWLEDGMENTS.

The author wishes to express his sincerest thanks to Prof. Clark for his valuable advice, encouragement and assistance during these investigations. The gracious facilities provided by the Director of Veterinary Services are gratefully acknowledged.

LITERATURE.

CLARK, R. (1948). The effect of some commonly used antifermentatives on the *in vitro* formation of gas in ruminal ingesta and its bearing on the pathogenesis of bloat. *Onderstepoort J.* Vol. 23, Nos. 1–2, p. 389.

CLARK, R. (1950). The use of antifrothing agents in the treatment of acute bloat. *J.S.A. Vet. Med. Ass.* Vol. 21, No. 4, pp. 173–178.

CLARK, R., and WEISS, K. E. (1952). Reflex salivation in sheep and goats initiated by mechanical stimulation of the cardiac area of the forestomachs. *Jl. S.A. Vet. Med. Assoc.* (in press).

COLE, H. H., HUFFMAN, C. F., KLEIBER, M., OLSON, T. M. and SCHALK, A. F. (1945). A review of bloat in ruminants. *J. An. Sci.* Vol. 4, No. 3, pp. 183–236.

COLE, H. H., MEAD, S. W. and REGAN, W. M. (1943). Production and prevention of bloat in cattle on Alfalfa pasture. *J. An. Sci.* Vol. 2, No. 4, pp. 285–294.

DOUGHERTY, R. W. (1942). Analysis of gas and ingesta of bloated cattle. *Am. J. Vet. Res.* Vol. 3, No. 9, pp. 401–402.

KICK, C. H., GERLAUGH, P. and SCHALK, A. F. (1937). Some factors affecting the length of time whole corn kernels are retained in the rumen of steers. *Am. Soc. An. Prod., Proc.,* Nos. 26–28, pp. 95–97.

McCANDLISH, A. C. (1937). Hoven or bloat in dairy cattle. XI Milchwirtschaftlicher Weltkongress, Berlin, I pp. 410–412.

MEAD, S. W., COLE, H. H. and REGAN, W. M. (1944). Further studies on bloat. *J. Dairy Sci.,* Vol. 27, pp. 779–791.

MEAD, S. W. and GOSS, H. (1936). Some results of eight years of investigation concerning the role of roughage in the diet of ruminants (Abstract). *J. Dairy Sc.,* Vol. 19, p. 465.

OLSON, T. M. (1942). Ruminal gases in normal and bloated animals (Abstract). *J. Dairy Sci.* Vol. 25, pp. 684–685.

QUIN, J. I. (1943). Studies on the alimentary tract of Merino Sheep in South Africa VIII. The pathogenesis of acute tympanites (Bloat). *Onderstepoort Jl.* Vol. 18, Nos. 1 and 2, p. 113.

QUIN, A. H., AUSTIN, J. A. and RATCLIFF (1949). A new approach to the treatment of bloat in ruminants. *J. Am. Vet. Med. Assoc.* Vol. 114, No. 866, p. 313.

WESTER, J. (1935). Orgaanziekten by de grote huisdieren. J. van Boeckhoven, Utrecht and Amsterdam.

WEISS, K. E. (1952). Physiological studies on eructation in ruminants. *Onderstepoort Jl.* (in press).