S. Afr. J. Anim. Sci. 12, 119 - 127 (1982)

EFFECTS OF PHYSICAL FORM AND ALKALI TREATMENT OF MAIZE GRAIN SUPPLEMENTS ON HAY INTAKE AND UTILIZATION BY STEERS

Receipt of M.S. 16–02–1982

H.H. Meissner, L.H.P. Liebenberg*, J.P. Pienaar, A.B. van Zyl and Brenda Botha

(Key words: *grain supplement, hay intake, performance*)
(Sleutelwoorde: *graansupplement, hooi-inname, prestasie*)

OPSOMMING: DIE INVLOED VAN FISIESE VORM EN ALKALIBEHANDELING VAN MIELIEGRAANSUPPLEMENTE OP HOOI-INAME EN -BENUTTING DEUR OSSE

Dit word dikwels gepostuleer dat die fisiese vorm van 'n graansupplement die inname en benutting van 'n ruvoer kan beïnvloed. Swak inname of benutting word gewoonlik toegeskryf aan 'n hoë fermentasietempo van die supplement, maar hierdie tempo kan verander word deur die fisiese vorm van die supplement te verander.

In hierdie studie is die fermentasietempo van mielies gevarieer deur heelpitte, NaOH behandelde heelpitte, mielies met 'n partikelgrootte van sowat 600μ en konvensionele mieliemeel (300 – 600μ partikels) te gebruik. Die mieliesupplemente is gevoer teen peile van 0,7 tot 5,6 kg/os/dag aan osse wat *ad lib* toegang tot *Eragrostis curvula* hooi gehad het.

Ruvoerinname het liniêr met 'n toename in aanvulling gedaal met geen aanduiding van 'n differensiële effek wat aan die fisiese vorm van die supplement toegeskryf kon word nie. Gevolglik was verskillende fermentasietempos van die supplemente waarskynlik nie oorsaaklik tot die onderdrukking van die inname van die *E. curvula* hooi nie.

Die groei- en voeromsettingsrangordes het min of meer ooreengekom met die rangorde van die skynbare verteerbaarhede van die supplemente. Die beraamde %VOM van die heelpitte, NaOH heelpitte, 600μ partikels en die mieliemeel was onderskeidelik 58, 78, 75 en 89%. Dit wou voorkom asof die NaOH behandeling ietwat swakker benut was as wat verwag is. Die resultate verskil van ander werk in die literatuur. Dit mag te wyte wees aan die feit dat 'n ander graansoort en/of ruvoer gebruik is.

SUMMARY:

It has often been proposed that the physical form of the grain supplement could affect the intake and utilization of forages. Suppression of forage intake or poor utilization appears to be a function of high fermentation rate which could be altered by manipulation of the physical form of the grain supplement.

In this study fermentation rate of maize grain was altered by using whole kernels, NaOH treated whole kernels, grain particles of about 600μ and conventional ground maize (300 to 600μ particles). These supplements were fed between 0,7 to 5,6 kg/head/day to steers consuming *Eragrostis curvula* hay *ad lib.*

Roughage intake exhibited a linear decline as the supplement increased with no evidence of a differential effect due to physical form of the supplement. Thus, different fermentation rates of the supplements were apparently not responsible for the suppression of intake of *E. curvula* hay.

Growth and feed conversion figures ranked more or less according to the apparent digestibilities of the maize supplements which were calculated as 58, 78, 75 and 89%DOM for the whole kernels, NaOH treated whole kernels, 600μ particles and ground maize respectively. The NaOH treatment appeared to have been utilized slightly poorer than what would have been expected. The results differ from other work in the literature. This could have been due to the difference in type of cereal and or roughage used.

---

* Present address: SAAU, P.O. Box 1508 Pretoria 0001.

Supplementation of forage with grain is very often not economical, primarily due to substitution effects which are influenced by among others quality of forage (Blaxter & Wilson, 1963; Leaver, 1973, Coleman, 1977) and apparently also by processing of the grain (Ørskov, Soliman & Macdearmid, 1978, Sriskandarajah, Ashwood & Kellaway, 1980). It would appear that the substitution results primarily from a time-lag and reduction in extent of fiber digestion (Ørskov, 1978; Mertens & Loften, 1980) and consequently in forage digestion which could lead to a reduction in forage intake (Campling & Murdoch, 1966; Tayler & Wilkinson, 1972; Golding, Moore, Franke & Ruelke, 1976).

Whole grain appears to be more favourable to hay intake and digestion than rolled grain (Mann & Ørskov, 1975; Ørskov & Fraser, 1975) because rolled or ground grain has a very rapid fermentation rate leading to low rumen pH and heavy interference with cellulose digestion. On the other hand whole grain may be digested poorly, especially in cattle larger than 300 kg (Hale, 1973; Broadbent, 1976; Nordin & Campling, 1976; Aerts, Cottyn, De Brabander, Boucqué & Buysse, 1978). This could be ascribed to the fact that whole grain is not necessarily cracked when consumed by cattle and consequently the starch granules are not exposed to microbial attack (Ørskov, 1978; Ørskov *et al* 1978).

It would thus appear that the grain should be manipulated by physical or other means to enable a fermentation rate somewhere between that of whole grain and the ground or rolled form. From the results by Liebenberg, Meissner and Pienaar (1979) on maize grain suspended in dacron bags in the rumen, maize with a particle size of 600μ and NaOH treated whole maize at a level of 2 – 5 g naOH/100 maize showed the desired fermentation rate. Both Ørskov *et al* (1978) and Sriskandarajah *et al* (1980) reported very favourable effects on forage intake with alkali treated barley supplements.

The object in this study was to determine whether maize grain with particle size of 600μ and alkali treated whole maize when compared to whole and ground maize, would result in acceptable intakes of hay and optimal efficiency of utilization of the grain supplement by steers.

Materials and Methods

1. **Animals**: A Homogenous group of 32 Sussex type steers with initial live mass of 280 kg were used in a growth trial lasting 3 months.

2. **Design**: The steers were allocated in a 4 x 8 factorial design to one of 4 treatments of maize and one of 8 levels of supplementation. The treatments were whole maize, maize with a particle size of ca 600μ, ground maize and NaOH treated whole maize. The 8 levels of supplementation were 0,7; 1,4; 2.1; 2,8; 3,5; 4,2; 4,9 and 5,6 kg per head per day. *Eragrostis curvula* hay, considered to be a medium quality hay, was given *ad lib* in a separate trough.

3. **Treatment procedures of maize**: For the 600μ particle size, whole maize was hammermilled through a 6 mm die and then sieved through a standard set of sieves (ASAE, 1975). The particles left on the sieve with 600μ apertures were used as experimental material. Thus, the particles were in fact 600μ or greater. For the alkali treatment, 5 g NaOH/100 g whole maize in a 50% solution was sprayed onto the maize and then left to dry for effective storage. Ground maize was all the material after hammermilling through a 6 mm die. A mean particle size of 300 – 600μ with a range of 150μ to 1,18 mm was obtained.

4. **N, Mineral and vitamin supplements**: N was supplied as a constant proportion of DE intake (Elliot, Reed & Topps, 1964; Balch, 1967). A mixture of urea and sunflower oilcake was used as a N supplement. These were given in a mixture with Ca, P, NaCl, minerals and vitamins (A.R.C., 1965) directly into the feed trough when the maize supplement was given.

5. **Digestibility study**: Faeces was collected for 6 days. Collection periods for the 32 steers were scattered at random throughout the growth trial. Samples of faeces and feed were analysed for DM and ash content to enable calculation of apparent DOM.

6. **Growth trial measurements**: Live mass and voluntary intake of every steer were recorded continuously for three months with 6 day intervals of measurement following an adaptation period of 2 weeks. The intake of hay and the supplement (when not completely consumed) was measured separately to enable separate statistical analysis.

7. **Statistical treatment**: The relationship between cumulative feed intake and live mass was described by linear regression on the log scale (Roux, 1976; Meissner, 1977). This procedure minimizes measurement error and enables calculation of a measure such as intake at a specific point of interest. The point of interest chosen for this discussion was the mean live mass of 320 kg. Calculated intakes of hay, hay plus maize and DOM at 320 kg live mass were regressed against level of supple-

Table 1

Parameters of the linear equation between level of maize supplementation (X) and intake of hay DM (Y) and the results of covariance analyses for differences between slopes and intercepts

Treatment	Slope	Intercept	r	F-values for differences between: Slopes	Intercepts
whole	– 0,368	4,316	– 0,926		
NaOH	– 0,597	4,629	– 0,954	2,39 NS	0,84 NS
600μ	– 0,430	4,401	– 0,841		
ground	– 0,651	5,078	– 0,941		

mentation or live mass gain. Differences between treatments were tested for by covariance analysis of the slopes and intercepts.

Results and Discussion

1. Influence of Maize form and level of supplementation on intake of Hay.

Table 1 shows the results of covariance analyses on the slopes and intercepts of the relationship between level of supplementation and intake of hay.

There were no significant differences between either of the parameters which suggest that form of maize did not influence hay intake differentially There appears to be some similarity between the NaOH and ground treatments on the one hand and the whole and 600μ treatments on the other. If tested as such, a significant difference was in fact found between slopes, but apparently of no valid consequence, since if it is assumed that the level of hay intake at zero supplementation should theoretically be the same (the figure of the intercept in Table 1), the difference disappears. One relationship describing level of supplementation versus intake of hay could consequently be calculated.

The relationship with best fit ($r = -0{,}902$) was.

$$Y = 4{,}62 - 0{,}514\ X$$

where,

X = level of supplementation in kg/day

Y = intake of hay DM in kg/day

The results are in accordance to the reports of amongst others, Campling & Murdoch (1966), Tayler & Wilkinson (1972) and Golding *et al* (1976) which also showed a reduction in roughage intake with increasing levels of supplementation. However, the results appear to be in conflict with the findings of Mann & Ørskov (1975), Ørskov & Fraser (1975), Ørskov *et al* (1978) and Sriskandarajah *et al* (1980) which indicate less depression of hay intake when whole or NaOH treated grain are used than when ground or rolled grain are used. A possible explanation for this apparent contradiction is not obvious, but different roughages, roughage particle sizes and different types of grain might show different responses. Both Ørskov and co-workers and Sriskandarajah *et al* used barley in their experiments whereas maize was used in the present study. It is well known that maize ferments slower than barley. These workers, of course, also used other types of roughages.

One could also have some reservations about the accuracy of the results. Although the method of analysis minimizes measurement error as discussed previously, the sensitivity of tests for significance was hampered by relatively large biological variation expressed in particular in intake of both the supplement and the hay. It should be mentioned as a matter of interest that a level of supplement intake of 5,6 kg per head per day was never achieved on any of the treatments and that the day to day intake on the higher supplementations varied considerably. In addition the response to the NaOH treatment should be considered with caution because the highest level of supplement intake achieved was only 3,8 kg per head per day. It would appear that the particular method of treatment employed could have been responsible for the palatibility problems. The dried product

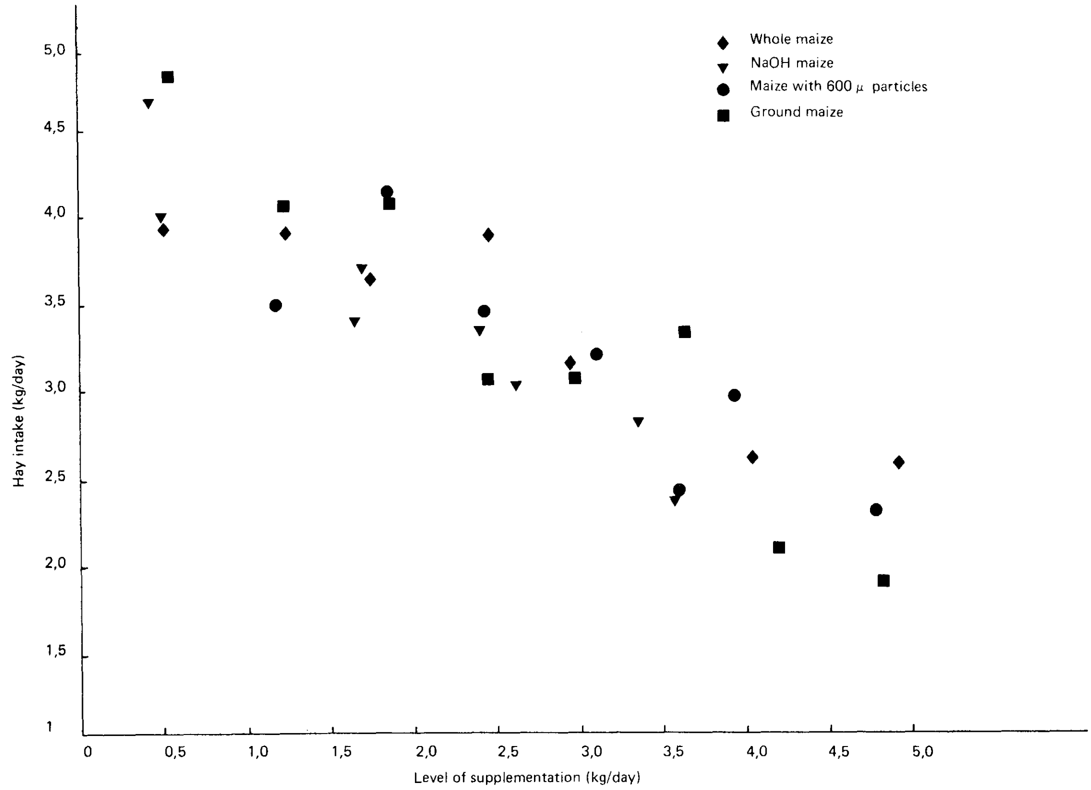

Fig. 1: *Hay intake at different levels of supplementation*

became very hard and obviously very difficult to chew. Low palatability may also be associated with high levels of residual alkalinity causing inflammation of the mouth and tongue (Sriskandarajah *et al*, 1980). One should preferably rinse the grain thoroughly before feeding.

However, having stated these probable explanations one should recognize the very clear evidence that there was not the slightest indication that hay intake was differentially influenced by maize form. This is apparent from Figure 1. Further evidence in this regard was that apparent crude fibre digestibility was also not differentially affected by treatment. A reduction in fibre digestion has been put forward as an explanation for the reduction in hay intake (Ørskov, 1978; Mertens & Loften, 1980). Also, in an unpublished experiment by Liebenberg, Meissner & van Zyl (1980) where solutions of H_2O, 0,1 % NaOH, 1,0 % NaOH and 1,5 % propionic acid respectively, were absorbed into whole maize to a final moisture level of 25 %, hay intake was linearly substituted for by maize supplement. The figures for hay and supplement for the four treatments were: 0,64; 6,19; 0,56; 6,53; 0,49; 6,92; 0,59; 6,25. The difference from the present report is that in the quoted experiment the maize constituted about 90 to 95 % of total intake. Total intake of DM, i.e. hay plus supplement with increasing levels of supplement showed a slope in the opposite direction to that of intake of hay. The best fit, with a correlation coefficient of 0,839 was achieved with the equation:

$$Y = 4,62 + 0,486\ X$$

where, X = level of supplementation in kg/day

Y = intake of hay plus supplement in kg/day.

The increase in total intake with level of supplementation is in accordance to many reports (Lake, Hildebrand, Clanton & Jones, 1974; Burris, Brown, Rogers, Tyner & Convillion, 1976; Coleman, Pate & Beardsley, 1976; Lowery, McCampbell, Calvert, Beaty & Woods, 1976). However, it would appear from the literature that the increase in intake might start levelling off at 3,5 to 3,75 kg supplement per head per day on forages of 55 to 60 % apparent digestibility. No such levelling off could be found within the limits of supplementation in this study with *Eragrostis curvula* hay which has a similar apparent digestibility. Apparent digestibility is however only one of the factors influencing the issue. Rate of

Table 2

Parameters of the linear equation between level of maize supplementation (X) and live mass gain (Y) and the results of covariance analyses for differences between slopes and intercepts

Treatment	Slope	Intercept	r	F-values for differences between Slopes	Intercepts
whole	0,115	0,195	0,787		
NaOH	0,078	0.269	0,728	0,47 NS	7,68**
600μ	0,135	0,217	0,871		
ground	0,102	0,451	0.900		

** P < 0,01

fermentation of the forage in the rumen could be more important (Pienaar, unpublished). The 4,9 kg level of supplementation which was the highest achieved realized the highest total DM intake. These observations were substantiated by the fact that second and third order polynomials did not result in significant improvement of fit above that of ordinary least squares analyses.

2. **Influence of maize from and level of supplementation on live mass gain.**

Table 2 shows the results of covariance analyses on the slopes and intercepts of the relationship between level of supplementation and live mass gain.

There were no significant differences between slopes but highly significant differences between intercepts in the relationship level of supplementation vs live mass gain. This clearly illustrate differences due to maize form. However, interpretation presents somewhat of a dilemma. Since intercepts differ from one another, it is implicated that gain would have been significantly different at zero supplementation, or that hay intake at zero supplementation would have been different between treatment groups, which of course is highly unlikely, Therefore, the relationships were recalculated using a common intercept of 0.284, while the slope adjusted to.

Whole and NaOH ca 0,086
600μ ca 0,113
ground ca 0,148

which suggests that the 600μ treatment gained more per level of supplementation than the whole and NaOH treatments, while the ground treatment gained more than the 600μ, whole and NaOH treatments.

The above equations suggest that live mass gain was the highest at the highest level of supplementation, i.e. at about 4,9 kg per head per day. One would have thought that gain could level off bearing in mind the results reported in the literature which show that the rate of gain with increasing levels of supplementation, especially above 3,75 kg., tend to decrease (Coleman *et al*, 1976; Perry & Beeson, 1976; Coleman, 1977). If so, however, the fit of second or third order polynomials should have been significantly better than the linear equation, which was not the case. Again, as stated earlier, the type of forage used is expected to have an influence on the results so that our results should not necessarily be in accordance to those of the quoted authors.

3. **Influence of maize form and level of supplementation on apparent digestibility of OM.**

The linear equation between level of supplementation and % DOM fitted with correlation coefficients of 0,115 (NS); 0,704; 0,825 and 0,909 for the whole, NaOH, 600μ and ground treatments respectively. Since it is a well known observation that feeding level in general influences apparent digestibility (e.g. Blaxter, 1962), and because feeding level increases with increasing levels of supplementation, feeding level was introduced as second independent variable in a multiple linear

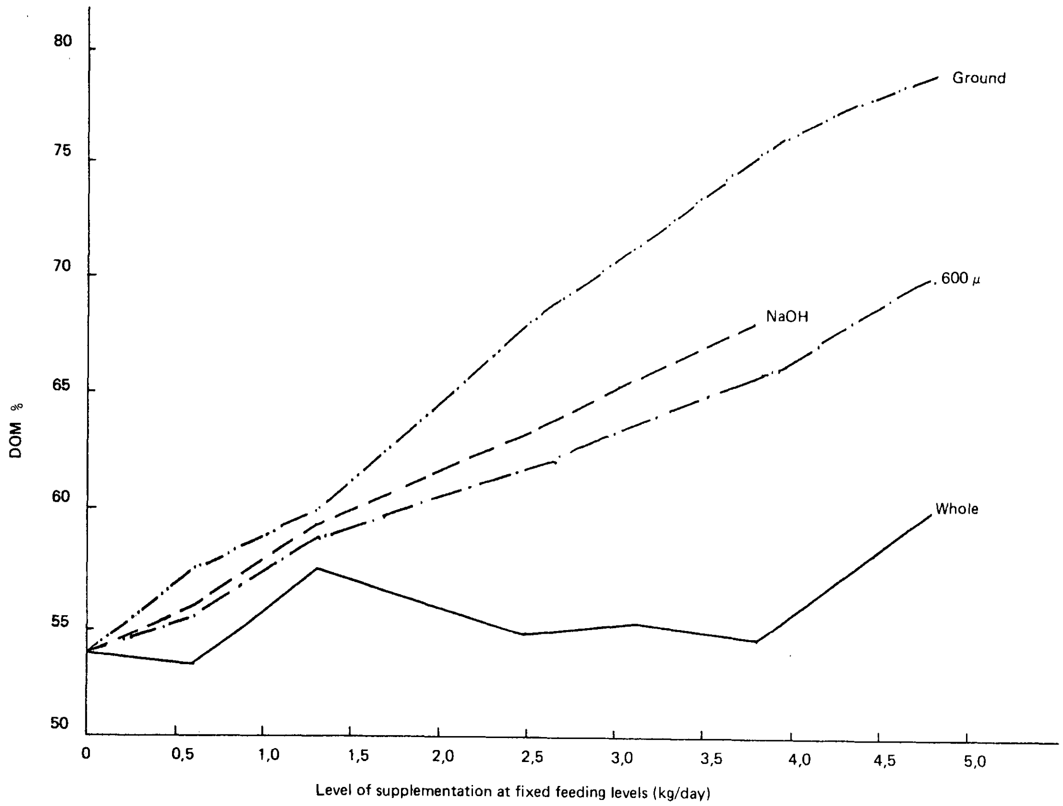

Fig. 2. *Feeding level between treatments was held constant at a specific level of supplementation*

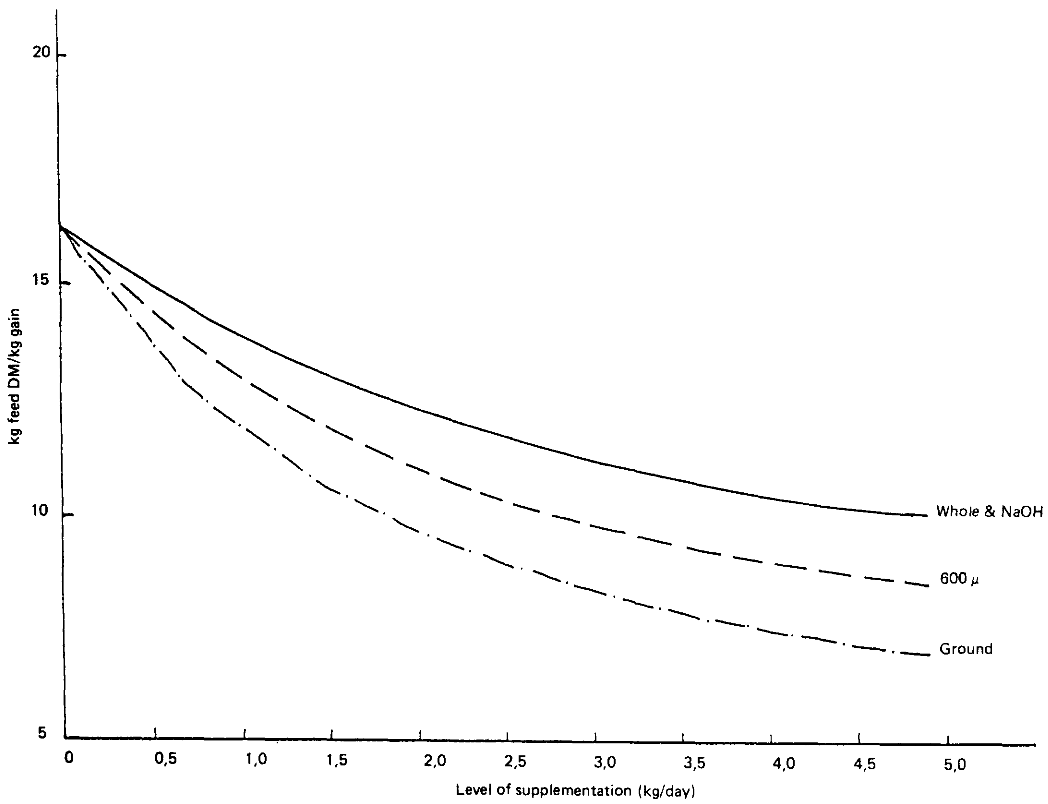

Fig. 3. *Feed conversion ratio at different levels of supplementation*

regression analysis to see if any improvement in fit results. Feeding level was calculated by expressing intake as a percentage of live mass.

Feeding level apparently did influence the relationship because (multiple) correlation coefficients improved to 0,669 (now significant); 0,739; 0,831 and 0,927 for the whole, NaOH, 600μ and ground treatments. Using these multiple linear regression equations, but adjusting to one intercept (the value at zero supplementation), Figure 2 was compiled. Order of rank in apparent DOM at the same feeding levels between treatments was ground > NaOH ≥ 600μ > whole. If the apparent DOM % of the hay is assumed to be 53,9 (Fig. 2), the feeding level to be 2% of live mass and the level of supplementation at 2,8 kg per head per day, the equations predict apparent DOM percentages of 89, 78, 75 and 58 for the ground, NaOH, 600μ and whole treatments respectively. The value for ground is what is usually being found, that of the NaOH and 600μ is about the same, but substantially higher than the 58% predicted for the whole. Poor digestibility of whole untreated maize has been found on a number of occasions (Hale, 1973; Broadbent, 1976; Nordin & Campling, 1976: Aerts, *et al*, 1978; Liebenberg, Meissner & van Zyl, 1980 (unpubl.)) with some figures being as low as 60%. Alkali treated grain usually show digestibilities between 70 and 80% depending on level of treatment (Ørskov, 1978; Ørskov *et al* 1978; Sriskandarajah *et al.* 1980; Liebenberg, Meissner & van Zyl, 1980 (unpubl.)) The present value falls within this range.

4. **Calculated feed conversion ratio as influenced by treatment and level of supplementation.**

The feed conversion ratios of the different treatments at the various levels of supplementation are illustrated in Figure 3.

The treatments whole and NaOH showed about the same feed conversion ratio, treatment 600μ was somewhat better and treatment ground was superior to all others. Feed conversion ratio also improved with level of supplementation irrespective of treatment. The results with NaOH is interesting. Despite a relatively high apparent DOM of 78% the efficiency of utilization for gain appears low. The explanation offered by Sriskandarajah *et al* could be applicable here. The end products of fermentation on their NaOH treatment showed proportionally less propionic acid than the rolled or cracked barley treatments which favoured milk production to the detriment of gain. The efficiency of utilization for gain was consequently lower on their NaOH barley treatments than on the other treatments.

On the other hand though, Ørskov, MacDearmid, Grubb & Innes (1981) presented evidence to show that the rumen contents are always considerably less with NaOH treated than rolled and presumably also ground grain. This could mean that the picture could be slightly different for feed conversion to carcass gain.

Conclusions

1. Hay intake was linearly and inversely related to level of maize supplementation within the limits of the experiment.

2. Hay intake was not differentially influenced by maize treatment, i.e. different particle sizes or alkali treatment of the supplement.

3. Total intake, i.e. hay plus supplement, increased linearly with level of supplementation within the limits of the experiment.

4. Apparent digestibility of maize OM was 58, 75, 78 and 89% for the whole, 600μ, NaOH and ground treatments respectively while the order of rank in live mass gain and feed conversion ratio as expressed from best to worst was ground, 600μ and NaOH and whole. While the other treatments showed the expected response, i.e. in accordance to their apparent DOM, the NaOH treatment did not. This probably means that the efficiency of utilization of the NaOH maize supplement for live mass gain was less than the efficiency of the others, which could be due to differences in the end products of fermentation.

5. The highest levels of supplementation showed the best results in terms of live mass gain and efficiency of feed conversion. The optimum financial result would depend on the price ratio between the hay and the maize supplement.

6. Since the ground maize supplement produced substantially better results than the others, it appears to be the preferred form for supplementation of hays such as *Eragrostis curvula.*

References

AERTS, J.V., COTTYN, B.G., DE BRABANDER, D.L., BOUCQUÉ, C.L.V. & BUYSSE, F.X., 1978. Effect of rolling or grinding maize grain on its nutritive value for sheep and cows. 29th Annual Meeting of EAAP, Stockholm 5–7/6/1978.

A.R.C., 1965. The nutrient requirements of farm livestock: No. 2. Ruminants. London: A.R.C.

A.S.A.E., 1975. Method for determining and expressing fineness of feed materials by sieving. ASAE S319 Agricultural Engineering Yearbook 1975, p. 436.

BALCH, C.C., 1967. Problems in predicting the value of non protein nitrogen as a substitute for protein in rations for farm animal ruminants. *World Rev. Anim. Prod.* 3, 84.

BLAXTER, K.L., 1962. The energy metabolism of ruminants. Charles C. Thomas, Springfield, Illinois, U.S.A.

BLAXTER, K.L. & WILSON, R.S., 1963. The assessment of a crop husbandry technique in terms of animal production. *Anim. Prod.* 5, 27.

BROADBENT, P.J., 1976. The utilization of whole or bruised barley grain of different moisture contents given to beef cattle as a supplement to a forage-based diet. *Anim. Prod.* 23, 165.

BURRIS, W.R., BROWN, W.E., ROGERS, R.W., TYNER, F.H. & CONVILLION, W.C., 1976. Supplemental grain for finishing steers on winter pasture. *J. Anim. Sci.* 42, 261 (Abstract).

CAMPLING, R.C. & MURDOCH, J.C., 1966. The effect of concentrates on the voluntary intake of roughages by cows. *J. Dairy Res.* 33, 1.

COLEMAN, S.W., 1977. Energy supplementation of grazing cattle. Proc. 10th Research Industry Conf., Columbia, Missouri, 14 – 16/2/1977. American Forage & Grassl. Council.

COLEMAN, S.W., PATE, F.M. & BEARDSLEY, D.W., 1976. Effect of level of supplemental energy fed to grazing steers on performance during the pasture and subsequent dry lot period. *J. Anim. Sci.* 42, 27.

ELLIOT, R.C., REED, W.D.C. & TOPPS, J.H., 1964. Studies of protein requirements of ruminants. 4 Liveweight changes of two breeds of African cattle given three levels of dietary protein each with varying amounts of digestible energy. *Br. J. Nutr.* 18, 519.

GOLDING, E.J., MOORE, J.E., FRANKE, D.E. & RUELKE, O.C., 1976. Formulation of hay-grain diets for ruminants. II. Depression in voluntary intake of different quality forages by limited grain in sheep. *J. Anim,. Sci.* 42, 717.

HALE, W., 1973. Influence of processing on the utlization of grain (starch) by ruminants. *J. Anim. Sci.* 37, 1075.

LAKE, R.P., HILDEBRAND, R.L., CLANTON, D.C. & JONES, L.E., 1974. Limited energy supplementation of yearling steers grazing irrigated pasture and subsequent feedlot performance. *J. Anim. Sci.* 39, 827.

LEAVER, J.D., 1973. Rearing of dairy cattle. 4. Effect of concentrate supplementation on the live-weight gain and feed intake of calves offered roughages *ad libitum. Anim.Prod.* 17, 43.

LIEBENBERG, L.H.P., MEISSNER, H.H. & PIENAAR, J.P., 1979. Disappearance of processed maize grain in the rumen. *S. Afr. J. Anim. Sci.* 9, 227.

LOWERY, R.S., MC CAMPBELL, H.C., CALVERT, G.C., BEATY, E. & WOODS, F., 1976. Effect of previous treatment and energy levels on finishing yearling steers on winter pasture. *J. Anim. Sci.*. 42, 260 (Abstract).

MANN, S.O. & ØRSKOV, E.R., 1975. The effect of feeding whole or pelleted barley to lambs on their rumen bacterial populations and pH. *Proc. Nutr. Soc.* 34, 63 A.

MEISSNER, H.H., 1977. An evaluation of the Roux mathematical model for the functional description of growth. Ph. D. Thesis, Univ. P.E., South Africa.

MERTENS, D.R. & LOFTEN, J.R., 1980. The effect of starch on forage fibre digestion kinetics *in vitro. J. Dairy Sci.* 63, 1437.

NORDIN, M. & CAMPLING, R.C., 1976. Digestibility studies with cows given whole and rolled cereal grains. *Anim. Prod.* 23, 305.

ØRSKOV, E.R., 1978. Processing of grain for ruminants. 29th Annual Meet. EAAP., Stockholm, 5–7/6/78.

ØRSKOV, E.R. & FRASER, C., 1975. The effects of processing of barley-based supplements on rumen pH, rate of digestion and voluntary intake of dried grass in sheep. *Br. J. Nutr.* 34, 493.

ØRSKOV, E.R., MAC DEARMID, A., GRUBB, D.A. & INNES, G.M., 1981. Utilization of alkali-treated grain; 1. Alkali-treated grain in complete diets for steers and lambs. *Anim. FD. Sci. Tech.* 6, 273.

ØRSKOV, E.R., SOLIMAN, H.S. & MAC DEARMID, A., 1975. Intake of hay by cattle given supplements of barley subjected to various forms of physical treatment or treatment with alkali. *J. Agric. Sci. Camb.* 90, 611.

PERRY, T.W. & BEESON, W.M., 1976. Ratios of corn to corn silage for finishing beef cattle. *J. Anim. Sci.* 42, 549.

ROUX, C.Z., 1976. A model for the description and regulation of growth and production. *Agroanimalia,* 8, 83.
SRISKANDARAJAH, N., ASHWOOD, A. & KELLAWAY, R.C., 1980. Effects of rolling and alkali treatment of barley grain supplements on forage intake and utilization by steers and lactating cows. *J. Agric. Sci. Camb.* 95, 555.
TAYLER, J.C. & WILKINSON, J.M., 1972. The influence of level of concentrate feeding on the voluntary intake of grass and on liveweight gain by cattle. *Anim. Prod.* 14, 85.