# PRODUCTION AND NUTRITIVE VALUE OF ALKALI-TREATED FORAGES

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## SUMMARY

A technique is described whereby low quality forage is sprayed with solutions of alkali and supplementary nutrients as it passes through the chute of a forage harvesting machine. The treated forage, known as 'Alkalage'† is directed into a baler, forage trailer or forage compression chamber; forage collected in bulk is stored in pit or tower silos.

Results of feeding experiments with cattle indicate that the technique effects substantial improvements in the nutritive value of cereal straws,

## INTRODUCTION

Production of cereal straw in Australia is about 29 million tonnes annually and much greater quantities of low quality forages are produced from native pastures. It is known that alkalis, particularly NaOH, increase the digestibility and intake of low quality forages (see review by Jackson 1977), provided that the supply of rumen-degradable nitrogen is adequate (Miller et al. 1977). Kellaway et al. (1978) reported a new farm technique for treating forages with solutions of alkali and supplementary nutrients in a continuous-flow process. This paper reports further development of the technique and on the nutritive value of the product, which has been called 'Alkalage'

## FORMULATION OF SOLUTIONS TO SPRAY FORAGES

### Supplementary nutrient solution

Comparisons of published analyses of the composition of Australian wheat straws with the dietary requirements of cattle indicate that, apart from their low digestibility, wheat straws are deficient in nitrogen, phosphorus and sulphur. Studies on apparent intestinal absorptions of amino acids in steers fed NaOH-treated wheat straw, sprayed with four levels of urea solution, showed that urea was utilised effectively and that the optimum level of application was about 28 g urea/kg air dry straw (Leibholz and Kellaway 1980).

Urea dissolves in its own weight of water in an endothermic process which is slow. For this reason, and also to ensure the stability of the prepared solution, urea is introduced into a mixture of acids and water during their exothermic reaction. The mixture contains 50 1 water, 34.7 1 black phosphoric acid + sulphuric acid (72 : 28 w/w) and 50 kg urea per 100 1 solution. When this acid solution is applied at the rate of 50 l/t straw, it supplies 11.5 g N (25 g urea), 1.6 g P and 1.2 g S/kg straw, which maintains a N : S ratio in the diet of 10 : 1 and supplies sufficient P to meet the likely requirements of adult cattle for maintenance. Formulation of this solution may be changed as information becomes available on efficiencies of mineral absorption and responses to mineral supplements in animals eating alkali-treated forages. Trace elements may be added to the solution to overcomelocal deficiencies in the forage.

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Alkali solution

The optimum level of NaOH for treatment of forages is 40-50 kg NaOH/t straw, when the treated forage is the main component of the diet (Jackson 1977). In the 'Alkalage' technique the alkali solution contains 66.8 1 water and 33.2 1 NaOH solution (50% w/w) per 100 1 solution. When this solution is applied at the rate of 190 l/t straw, it supplies 48 kg NaOH/t straw, of which 8 kg NaOH is neutralized by the acid solution. The total amount of water applied in the alkali and supplementary nutrient solutions is 200 kg/t straw.

## EQUIPMENT USED FOR 'ALKALAGE' PRODUCTION

Spray tanker

The spray tanker consists of a two-wheel trailer on which are mounted a 2400 1 tank for the alkali solution, a 900 1 tank for the acid solution, a 50 1 tank for water, two pumps driven by a petrol engine, flow gauges, pressure gauges and control valves operated electrically from the tractor cab. The alkali and acid tanks are constructed from fibreglass, using resins resistant to the chemicals. The water tank is fitted with a tap for use in washing in case of accidental spillage on the operator.. The contents of the acid and alkali tanks are sufficient to spray 13 t forage.

Forage harvesting machines

(i) Forage harvesters, both single and double chop, are suitable, although a better spray coverage is achieved with fewer spray jets in the latter machines. Double chop harvesters are modified by fitting four jets around the base of the chute, through which alkali solution is pumped, and one jet higher up on the chute, through which acid solution is pumped. The spray trailer is towed behind the forage harvester.

(ii) 'Stak Hand' harvesters are comprised of a single chop forage harvester connected to a forage compression chamber. These machines are modified by fitting eight jets, equally spaced around the middle of the chute, through which alkali solution is pumped, and two jets lower down on the chute, through which acid solution is pumped. The spray trailer is towed alongside the 'Stak Hand' using a tow bar which slots into a tube on the 'Stak Hand' chassis.

Forage collection and storage

'Alkalage' from forage harvesters has been directed into a hay baler or a tipping trailer driven alongside. The hay baler is modified by fitting a hopper above the pickup drum. 'Alkalage' collected in bulk in a tipping trailer has been transferred to pits, consolidated by pushing with a front-end loader, and covered with a sheet of polythene.

'Alkalage' from 'Stak Hand' harvesters emerges from the machine as ready-made stacks which are left in the paddock until required for feeding.

## NUTRITIVE VALUE OF 'ALKALAGE'

When wheat straw was treated using the 'Alkalage' technique, % digestible organic matter in dry matter (DOMD) increased from 38 to 53 and the growth rates of heifers eating untreated and treated straws were -312 and +23 g/day respectively. When oat straw was similarly treated, % DOMD was increased from 47 to 58 and heifers eating the untreated and treated straws grew at 143 and 564 g/day respectively (Kellaway et al. 1978). In both these experiments the straw was baled.

In a subsequent experiment, the 'Alkalage' techniques were tested on a larger scale on a property near Wagga.

## Materials and methods

Wheat straw (var. Olympic) was harvested with a 'Gehl 72' forage harvester and a 'Stak Hand 30A' harvester, both of which were adapted for 'Alkalage' production as described previously. The straw was sprayed with urea + minerals (U) and with NaOH + urea + minerals (A). At this stage in development of the technique, phosphoric acid was pumped through the acid system and a solution of urea and NaHSO was mixed into the alkali tank before spraying. The amounts of N, P and S app4ied were as described above. Forage from the 'Gehl 72' was stored in pits and that from the 'Stak Hand 30A' was left in stacks.

Fifteen Hereford steers were allocated to each of the four treatments in four separate' yards. Animals were fed through self-feeding grids which were moved regularly to maintain ad lib. access to the forage. Live weights were recorded weekly, forage samples were collected at the start of the trial and rumen liquor samples at the end of the trial.

## Results and discussion

TABLE 1 Composition of wheat straw sprayed by 'Alkalage' techniques with urea + minerals (U) and with NaOH + urea + minerals (A), stored in pits (P) and in stacks (S). Liveweight changes, over 49 days, of Hereford steers (15/treatment) eating the forages, and composition of their rumen fluid.

| Storage system | P | | S | | SEM | F test |
|---|---|---|---|---|---|---|
| Chemical treatment | U | A | U | A | | |
| DOMD in vitro (%) | 49 | 62 | 47 | 54 | | |
| NDF (g/kg DM) | 814 | 745 | 855 | 765 | | |
| Ash (g/kg DM) | 42 | 84 | 39 | 78 | | |
| Nitrogen (g/kg DM) | 11.2 | 13.7 | 11.5 | 10.8 | | |
| Initial live weight (kg) | 236 | 238 | 239 | 237 | | |
| Liveweight change (g/day) | -56 | +337 | -239 | +68 | 52.0 | A>U*** P>S*** |
| Rumen VFA (mM/l) | 35 | 53 | 35 | 32 | 6.4 | P>S** |
| Rumen $NH_3$ (mg/l) | 74 | 35 | 94 | 40 | 8.1 | U>A*** |

** P <0.01; *** P < 0.001

Differences in ash contents between U and A treatments were 42 and 39 g/kg on P and S storage systems respectively, which corresponded approximately with a difference of 44 g/kg expected from the amount of NaOH applied. NaOH treatment increased DOMD more in the pit than in the stack storage system. This difference probably was attributable to differences in the forage harvesting machines, whereby coverage of the straw with alkali solution was more effective in the 'Gehl 72' harvester due to the smaller cross-sectional area of its chute and the greater extent of forage comminution by its double-chop action.

The mean content of nitrogen in sprayed straws was 11.8 g/kg compared with 5.5 g/kg in unsprayed straw collected from the same paddock. The intended rate of nitrogen application from urea was 11.5 g/kg; thus it appears that 55% of nitrogen was lost. There was loss of $NH_3$ from the tank before spraying and for this reason urea is now applied from the acid tank as described earlier. However, experience from a current experiment indicates that this apparent loss of nitrogen may have been an artefact of the forage sampling technique. When forage samples sprayed with urea solution are mixed vigorously during sub-sampling, up to 50% of the urea can be shaken off. Rumen concentrations of VFA were higher and of ammonia lower in cattle eating NaOH-treated straw than in cattle eating untreated straw, which indicates that microbial fermentation was more active in animals eating the NaOH-treated straw.

Despite technical difficulties, animal responses were large, indicating that the technique upgraded the nutritive value of the straw sufficiently to convert it from a sub-maintenance diet into a diet on which modest growth was possible. The significantly better performance of cattle eating forages from the pits may be attributable to the shorter length of these forages collected by the double-chop forage harvester. If this is confirmed, it is possible that 'Stak Hand' harvesters could be adjusted to chop forages to a shorter length.

## ECONOMICS OF 'ALKALAGE' PRODUCTION

Costs of producing 'Alkalage' are $36-50/t forage, comprising $27 for chemicals and $9-23/t for labour and depreciation of equipment, based on the production of 600-200 t 'Alkalage' per annum respectively. The low cost and effectiveness of the techniques described suggest that they should have widespread application.

## ACKNOWLEDGEMENTS

Development of these techniques was made possible by financial supportfrom the Reserve Bank, Australian Meat Research Committee, ICI Australia Pty. Ltd., University of Sydney, donations of chemicals from ICI Australia Pty. Ltd., Ajax Chemicals Ltd., Australian Fertilizers Ltd., loans of equipment by Rheem Australia Ltd., Napier Grasslands Pty. Ltd., Fiat of Australia Pty. Ltd., provision of facilities and services by Grosvenor International, Agricultural Investments Australia Ltd., Mr. H. Fairfield-Smith and technical assistance from Mr. C. Stimson.

## REFERENCES

JACKSON, M.G. (1979). Anim. Feed Sci. Technol. 2: 105.

KELLAWAY, R.C., CROFTS, F.C., THIAGO, L.R.L., REDMAN, R.G., LEIBHOLZ, J.M.L. and GRAHAM, C.A. (1978). Anim. Feed Sci. Technol. 3: 201.

LEIBHOLZ, JANE and KELLAWAY, R.C. (1980). Proc. Aust. Soc. Anim. Prod. 13: 481.

MILLER, E.L., JOHNSON, I.L., BRIGGS, M.C.E. and KEMPSEY, R.G. (1977). Proc. Nutr. Soc. 36: 129A.