Journal of Animal and Veterinary Advances 9 (18): 2432-2436, 2010
ISSN: 1680-5593

Nutrient Content and *In sacco* Degradation of Hydroponic Barley Sprouts Grown Using Nutrient Solution or Tap Water

D.D. Dung, I.R. Godwin and J.V. Nolan
Animal Science, School of Environmental and Rural Science,
University of New England, Armidale, NSW 2351, Australia

Abstract: A hydroponic nutrient solution was used to raise barley sprouts to compare with sprouts raised using tap water irrigation (two treatments). In both treatments, the sprouts were raised in continuous light in a temperature-controlled room for a period of 7 days. There was no difference ($p>0.05$) in DM loss after 7 days of sprouting. The DM losses after 7 days of sprouting were 16.4 vs. 13.3% for tap water irrigation and hydroponic nutrient solution, respectively. Sprouts grown with nutrient solution had a higher protein concentration than those grown with tap water irrigation (17.3 vs. 15.9%), respectively. There was however, no difference ($p>0.05$) in *in sacco* degradation of sprouts in the rumen of Merino sheep. There was no advantage in the use of nutrient solution for producing hydroponic sprouts compared to sprouting with tap water only. If these sprouts were fed to ruminants, the DM losses would have represented a loss in digestible energy which would otherwise have been available for productive purposes. On a large scale these losses could add to the cost of animal production.

Key words: Tap water, nutrients, sprouts, degradation, sprouts, digestible energy

INTRODUCTION

Most of the research on hydroponic barley sprouts indicated a loss in DM after a week long sprouting as well as changes in composition of nutrients (Sneath and McIntosh, 2003). There have been different types of cultural practices used both at experimental and commercial sprouts production levels aimed at optimizing production (Morgan *et al*., 1992). Some of these practices are claimed to be useful in the reduction of DM losses in the week long sprouting exercise.

Reports on the use of nutrient solution for sprouting in comparison to tap water usage are conflicting with regards to DM losses and nutrient profile. Morgan *et al*. (1992) reported little effect on DM when they compared sprouting with tap water and two levels of nutrient solution while (Massantini and Magnani, 1980) noted a positive response to added nutrient solution which was temperature dependent.

This study was therefore designed to test the effect of the use of a nutrient solution while sprouting barley grain in comparison to the use of tap water only.

MATERIALS AND METHODS

Production of 7 days old sprouts: The barley variety Grimmett was used. This was a recommended variety by the Department of Primary Industries and Fisheries of Queensland Government for use in Southern Queensland and Northern New South Wales, Australia. A temperature controlled room with continuous lighting was used. Seeds of Grimmett barley were pre-steeped for 4 h in 0.1% (v/v) hypochlorite solution before being transferred onto watering trays where they were watered for 3 min at 2 h intervals over 7 days in continuous fluorescent light of 615 lux at the surface of the trays used for sprouting. Watering was done using either tap water or a hydroponic nutrient solution (Table 1).

The seeds were placed at a rate of 6.7 kg m^{-2}. Daily samples were taken for assessment of DM changes while at day 7, samples were taken for determination of profile of nutrients as well as DM for the two treatments.

Daily sprouts samples taken were weighed and stored at -20°C and at the end of the 7 days collection period, a Martin Christ freeze dryer was used to dry the samples. A control consisting of trays of unsprouted barley seeds was used to compare with the two sprouting treatments.

A known weight of the control barley that had been similarly stored was placed in the freeze dryer and given the same treatment conditions as the sprouts. The DM content over the 7 days sprouting period was determined by freeze-drying while the nutrient profile was determined according to AOAC (2000), the ICP-OES method for mineral profile, bomb calorimeter for gross

Corresponding Author: D.D. Dung, National Animal Production Research Institute, Ahmadu Bello University, P.M.B 1096, Zaria, Nigeria

energy in MJ kg^{-1}, micro-Kjeldahl digestion and distillation for total nitrogen. The same chemical analysis was done for the control which was the freeze-dried, unsprouted barley grain.

Nylon bag degradation of sprouts

Animals and housing: Four Merino sheep (initial weight of 45±5.2 kg) were housed in individual pens in an animal house. Each was fitted with a permanent rumen cannula.

Diets and feeding: The animals were fed oaten chaff *ad libitum* and were allowed to adjust to the diet for a period of 7 days before they were used for the nylon bag degradation study. A 15 g premix of vitamins and minerals was given per head daily as well as 50 g of cracked barley grain. Water was freely available. Fresh samples of 7 days sprouts were separated in shoot and root fractions; another set of whole sprouts were chopped and prepared for the nylon bag study. About 5 g of the sprouts portions were weighed into nylon bags of 140×70 mm and a pore size of 50 μm then incubated in the rumen for 6, 12, 24, 48, 72 and 96 h. The bags containing samples were withdrawn from the rumen at the specified intervals and the activities of enzymes stopped by placing the bags on ice. The bags and their contents were then washed thoroughly before they were freeze-dried and weighed for determination of DM disappearance. The DM percentage of freeze-dried samples was used to determine the DM disappearance of the rumen-incubated samples. The percentage degradation was a proportion of the residue over the initial sample expressed as a percentage.

Experimental design and statistical analysis: A completely randomized design with four replications of the two treatments was used (Steel and Torrie, 1980). The changes in DM over the 7 days for the two sprouting treatments were compared using paired t-tests. All data from the analyses were expressed on a DM basis. The control (unsprouted barley) was used as baseline information to observe the changes in nutrient profile of the two irrigation methods.

Table 1: Nutrient composition of hydroponic nutrient used in barley seed irrigation

Nutrient	Amount (ppm)
Ca	89.20
K	81.90
N	75.10
Fe	1.80
Mg	20.80
S	43.20
P	3.20
Zn	0.40
Mn	0.50
Cu	0.01
Bo	0.10
Na	0.10

RESULTS AND DISCUSSION

Fresh weight and dry matter changes in sprouts: Fresh weight changes are shown in Fig. 1. There was a gradual increase in fresh weight of the sprouts from day 1-7 of sprouting resulting in about a fourfold increase in fresh weight. The rise in fresh weight of the sprouts did not differ ($p>0.05$) due to treatment.

The DM concentration of hydroponic barley sprouts grown using tap water or nutrient solution declined during the sprouting process as shown in Fig. 2. There was no difference ($p>0.05$) in DM concentration between treatments.

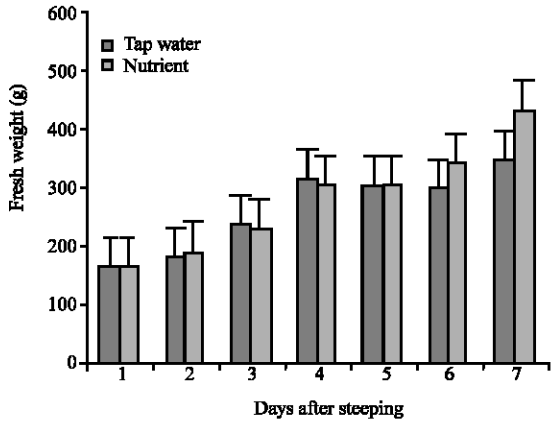

Fig. 1: Daily fresh weight increase of Grimmett barley during sprouting using tap water or hydroponic nutrient solution

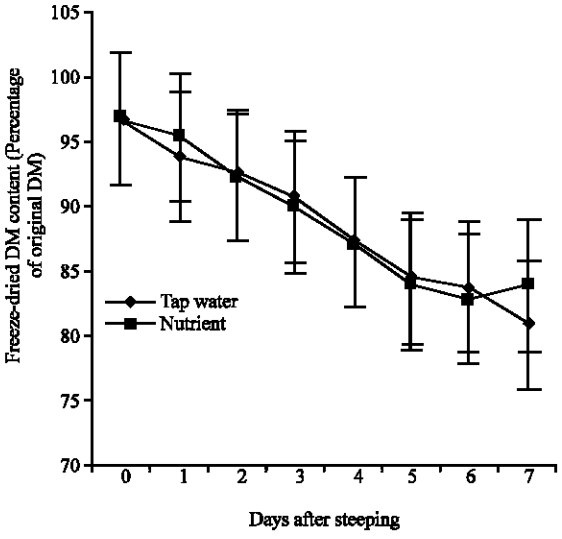

Fig. 2: Dry matter loss in Grimmett barley over a 7 days sprouting period using tap water or hydroponic nutrient solution

Table 2: Nutrient profile of Grimmett barley grain and sprouts irrigated with tap water or nutrient solution

Component	GE+	CP	Ash	Ca	K	Mg	Na	P	S	Al	Bo	Cu	Fe	Mn	Mo	Zn
	(DM%)									($\mu g g^{-1}$ DM)						
Grain	15.4	13.9	2.0	0.05	0.40	0.13	0.01	0.4	0.20	28.8	2.9	7	80.8	22.1	1.8	48
Sprouts-nutrients	14.9	15.9	4.3	0.08	0.36	0.15	0.07	0.4	0.20	19.8	2.4	16.7	114	19.6	1.2	57
Sprouts+nutrients	14.8	17.3	5.5	0.13	0.67	0.19	0.21	0.5	0.24	15.1	3.3	8.05	153	38.2	2.2	72

GE+ = Gross Energy (MJ kg^{-1} DM)

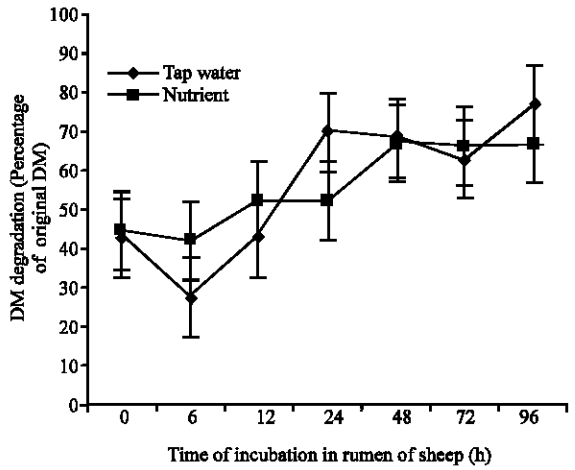

Fig. 3: Nylon bag degradation of Grimmett barley sprouts irrigated with water or hydroponic nutrient solution

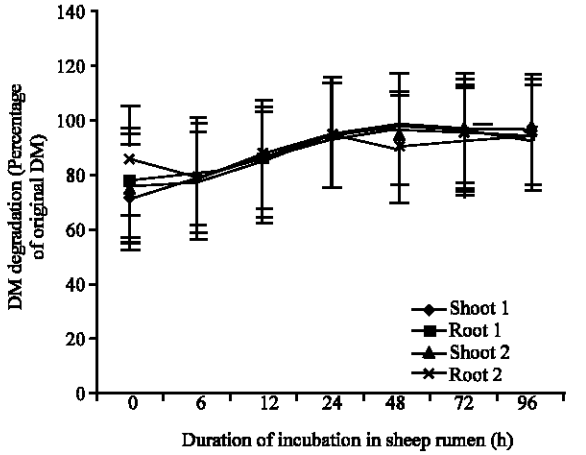

Fig. 4: Nylon bag degradation of shoot and root portions of Grimmett barley sprouts irrigated with hydroponic nutrients (1) or tap water (2)

Nutrient profile: The DM content, gross energy, crude protein and mineral profile of the original Grimmett barley grain as compared to the two irrigated barley sprout types at day 7 are shown in Table 2. Notable differences were that the CP and ash levels were higher for the sprouts and highest for those grown in the nutrient solution.

The hydroponic barley sprouts produced using a hydroponic nutrient solution had higher concentrations on a DM basis of all mineral elements except aluminium and copper than the barley grain and the hydroponic barley sprouts raised using tap water only.

Nylon bag degradation: The results of degradation of whole sprouts are shown in Fig. 3 while the degradation of the root and shoot portions for both irrigation types are shown in Fig. 4. There were no differences ($p>0.05$) between the degradation of the whole hydroponic barley sprouts irrigated using tap water or nutrient solution. The shoot and root portions of the hydroponic barley sprouts produced by tap water irrigation or nutrient solution did not differ ($p>0.05$) in nylon bag degradation in the rumen. Both fractions were highly degraded in the rumen when degradation figures were compared with the whole plant material shown in Fig. 3. The shoot and root portions were devoid of the fibrous seed husk unlike the whole plants shown in Fig. 3. Both hydroponic barley sprouts irrigated with tap water and nutrient solution showed a weight increase over time during the sprouting process consistent with reports in earlier studies (Dung *et al*., 2005). In experiment 1, the weight increase was up to 3.7 times the original seed used. A 5.7 fold increase after 7 days sprouting was reported by Peer and Leeson (1985). The increase in fresh weight was due to the large water uptake experienced during the germination. When seeds imbibe water they swell thereby increasing in size and weight. The increase in size caused the seed coat and part of the endosperm to split, leading to more absorption of water. When root development ensues there is usually more absorption of water with increase in irrigation leading to further increase in fresh weight. Another factor that would cause an increase in ash content of the sprout is the absorption of minerals from a hydroponic nutrient solution and this also leads to an increase in fresh weight.

The fresh weight of hydroponic barley sprouts did not differ ($p>0.05$) between treatments but the weight increases in the current study were lower than increases of 5-8 times reported by commercial hydroponics growers (Sneath and McIntosh, 2003). The likely causes for the differences in weight increases could be grain quality and variety used, nutrient solution used during sprouting, lighting, irrigation frequencies, seed treatment, water quality and pH, seeding density or growth duration (Morgan *et al*., 1992) or simply the degree of drainage of water from freshly irrigated sprouts. The steeping of barley grain followed by irrigation for 7 days resulted in a

gradual loss of DM by the hydroponic barley sprouts raised with tap water or nutrient solution. The DM losses on day 7 of sprouting were 16.6 and 13.3% for tap water irrigation and nutrient solution, respectively. DM losses of 9.4-18% following the sprouting of cereals for 5-7 days have been reported (Chung *et al*., 1989; Hillier and Perry, 1969; Morgan *et al*., 1992; Peer and Leeson, 1985). Leaching of material from the seed following soaking as well as oxidation of substrates from the seed was reported as the cause of the loss in DM from the original weight of seed (Chavan and Kadam, 1989). Leaking of solutes was reported to be fastest at the start of water uptake and comes to a halt after about 1 day (Simon, 1984).

Seed soaking leads to the activation of enzymes and solubilisation and digestion of the starch stored in the endosperm to simple sugars. This provides substrate for the young developing plant for metabolic activities. These substrates are respired to produce energy, giving off carbon dioxide and water. This loss of carbon dioxide leads to a loss in DM. The lighting in the sprouting chamber was not sufficient to permit any significant photosynthetic activity that could counteract the loss of DM resulting from respiration. Photosynthetic activity in the weeklong sprouting process does not commence until about day 5 when chloroplasts are activated and there is not enough time and lighting for any significant DM accumulation. In a lighted experiment DM losses continued to increase from a value of 5.2-12.3% after 6 days reflecting the losses due to respiration and the negligible amount of photosynthesis by young seedlings (Trubey *et al*., 1969).

The values for CP content were lowest for the barley grain followed by that of hydroponic barley sprouts irrigated with tap water then the hydroponic barley sprouts irrigated with a nutrient solution. The higher CP value for the hydroponic barley sprouts was however not a true reflection of protein increase but a response to dilution because of general loss in carbohydrate content through respiration. The higher CP and mineral concentrations of the hydroponic barley sprouts irrigated using a nutrient solution above that of the hydroponic barley sprouts irrigated with tap water was expected because of uptake of nitrogenous compounds (measured as CP) and mineral elements in solution by the former. Aluminium and copper, however were lower in concentration in the sprouts with mineral nutrient solution than tap water irrigation. This is unexplained.

The ruminal degradation of whole hydroponic barley sprouts (Fig. 3) did not differ ($p>0.05$) between treatments. In both sprouts (nutrient and tap water), the 0 h degradation had higher values than the 6 h. The 0 h was determined outside the rumen by hand-washing which likely caused some physical damage to the plant material, thereby releasing some cell contents. Freezing and thawing during storage would have further released more cell contents. When the plant materials were placed in nylon bags inserted directly into the rumen there was no chance for any physical damage that would have occurred through mastication in the mouth. Mastication during ingestion of fresh herbage (fresh ryegrass) was reported to cause a release of about 50% of soluble carbohydrates and 30% of intracellular nitrogen (Boudon and Peyraud, 2001; Mangan *et al*., 1976).

The nylon bag degradation of leaf and stem portions of both sprout types (tap water vs. nutrient solution) in the current study did not differ ($p>0.05$) as expected due to the similarity in composition of the material, comprising mainly of primary cell walls which are tender and highly degradable. The shoots and roots were easily degraded to smaller particle sizes which normally encourage lower retention time and passage rate from the rumen (Lamb, 1996; Laredo and Minson, 1975; Minson, 1990).

CONCLUSION

The present study had similarities with the earlier studies by the researcher (unpublished) where sprouting gave rise to losses in DM over a 7 days sprouting period mainly due to respiration losses. There was no adequate time and light intensity to compensate for losses in DM through photosynthetic activities. The average DM losses at day 7 of sprouting were 16.4 vs. 13.3% for hydroponic barley sprouts irrigated with tap water and nutrient solution, respectively.

If these sprouts had been used as feed for ruminants, the DM losses would have represented a loss in digestible energy which could otherwise have been available for productive purposes. On a large scale these losses would add to the cost of animal production.

Provision of nutrients in the hydroponic solution had no effect on DM yield as corroborated by Morgan *et al*. (1992). Following the loss of DM there was also no difference ($p>0.05$) in nylon bag degradation of hydroponic barley sprouts irrigated with tap water vs. nutrient solution. The short growth cycle of 7 days does not therefore seem likely to be adequate to bring about the desired changes that would encourage the use of a nutrient solution. The higher concentrations of CP and mineral elements recorded for the hydroponic barley sprouts produced using a nutrient solution did not seem to facilitate the needed microbial activity desired to give a higher degradation than the treatment without nutrient solution.

ACKNOWLEDGEMENTS

The researchers would like to acknowledge the technical assistance of Graham Chaffey, Jenny Wittig, Gary Taylor and David Creed during the conduct of the experiment. The research was made possible by the University of New England Scholarships (International Postgraduate Research Scholarship and University of New England Research Assistantship).

REFERENCES

AOAC, 2000. Official Methods of Analysis. 17th Edn., Association of Official Analytical Chemistry, Arlington, Virginia, USA.

Boudon, A. and J.L. Peyraud, 2001. The release of intacellular constituents from fresh ryegrass (*Lolium perenne*) during ingestive mastication in cows: Effect of intracellular constituent, season and stage of maturity. Anim. Feed Sci. Technol., 93: 229-245.

Chavan, J.K. and S.S. Kadam, 1989. Nutritional improvement of cereals by sprouting. Critical Rev. Food Sci. Nutr., 28: 401-437.

Chung, T.Y., E.N. Nwokolo and J.S. Sim, 1989. Compositional and digestibility changes in sprouted barley and canola seeds. Plant Foods Hum. Nutr., 39: 267-278.

Dung, D.D., I.R. Godwin and J.V. Nolan, 2005. Nutrient content and in sacco digestibility of Grimmett barley grain and sprouts. Anim. Nutr. Aust., 15: 167-167.

Hillier, R.J. and T.W. Perry, 1969. Effect of hydroponically produced oat grass on ration digestibility of cattle. J. Anim. Sci., 29: 783-785.

Lamb, J.B., 1996. Plant maturity effects on intake, digestibility and rumen kinetics of leaf and stem fractions of sandhills grasses in beef steers. Ph.D. Thesis, University of Nebraska.

Laredo, M.A. and D.J. Minson, 1975. The pepsin soluble dry matter of leaf and stem fractions of grasses in relation to voluntary intake by sheep. Aust. J. Exp. Agric. Anim. Husband., 15: 203-206.

Mangan, J.L., R.L. Vetter, D.J. Jordan and P.C. Wright, 1976. The effect of condensed tannins of sainfoin (*Onobrychis viciifolia*) on the release of soluble leaf protein into the food bolus of cattle. Proc. Nutr. Soc., 35: 95A-97A.

Massantini, F. and G. Magnani, 1980. Hydroponic fodder growing: Use of cleaner separated seed. Proceeding of the 5h International Congress on Soilless Culture.

Minson, D.J., 1990. Forage in Ruminant Nutrition. Academic Press, New York.

Morgan, J.V., R.R. Hunter and R. O'Haire, 1992. Limiting factors in hydroponic barley grass production. Proceedings of the 8th International Congress on Soilless Culture, Oct. 2-9, Hunter's Rest, South Africa, pp: 241-261.

Peer, D.J. and S. Leeson, 1985. Nutrient content of hydroponically sprouted barley. Anim. Feed Sci. Technol., 13: 191-202.

Simon, E.W., 1984. Early Events in Germination. New South Wales Academic Press, Australia.

Sneath, R. and F. McIntosh, 2003. Review of Hydroponic Fodder Production for Beef Cattle. Queensland Government, Department of Primary Industries, Dalby, Queensland.

Steel, R.G.D. and J.H. Torrie, 1980. Principles and Procedures of Statistics. 2nd Edn., McGraw Hill Book Co. Inc., New York, USA., ISBN-13: 9780070610286, pp: 188-189.

Trubey, C.R., C.L. Rhyckerd, C.H. Noller, D.R. Ford and J.R. George, 1969. Effect of light, culture solution and growth period on growth and chemical composition of hydroponically produced oat seedlings. Agron. J., 61: 663-665.