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Research Application Summary

Evaluation of the effectiveness of hydroponically produced pigeon pea fodder versus grain based supplements for improved dairy cow production performance

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Abstract

An on-station feeding trial was conducted to evaluate the effectiveness of using hydroponically produced pigeon pea fodder as a feed supplement against grain-based feed supplements on dairy cow production performance in Malawi. Six multiparous Holstein-Friesian x Malawi Zebu cross-bred dairy cows were allocated into three groups with each group having a cow in mid and late lactation. The groups were systematically assigned to three diet supplements [Diet A: Hydroponically produced pigeon pea fodder; Diet B: raw pigeon pea and Diet C: roasted pigeon pea] instead of Centrosema pubescens over three periods in a 3 x 3 cross-over design. Each feeding period lasted for two weeks which was followed by a week of resting to avoid a diet carry-over effect. Data collected included daily milk yield, milk samples, weight at fortnight interval and costs. Milk samples were analysed using a digital milk analyser (Milk- Lab Compact). All data were managed and analysed in Statistical Package for Social Sciences. The results indicated that during adaptation and resting periods, the daily milk yield per cow was significantly ($p < 0.05$) lower than during the treatment periods. However, all the three treatment diets (A, B and C) did not significantly differ ($p > 0.05$) in influencing daily milk yield, milk composition (except fat) and daily weight gain of the cows. Economic analysis results on the other hand showed that supplementing lactating cows with diet A was 26% cheaper than diets B and C. In conclusion, hydroponically produced pigeon pea fodder was less expensive feed supplement when compared to grain-based feed supplements and resulted in similar influence in improving daily milk yield, milk composition and average daily weight gain. These results suggest that using hydroponically produced pigeon pea fodder in comparison to grains as feed supplements, may be an economically sound alternative feeding management solution for farmers during the long dry season in Malawi.

Keywords: Feed supplements, least cost, Malawi, milk composition, milk yield

Résumé

Un essai d'alimentation en station a été mené pour évaluer l'efficacité de l'utilisation du fourrage de pois cajan produit par hydroponie comme complément alimentaire par rapport aux compléments alimentaires à base de céréales sur la performance de la production de vaches laitières au Malawi. Six vaches laitières croisées multipèdes Holstein-Friesian x Malawi Zebu ont été réparties en trois groupes, avec chaque groupe ayant une vache en milieu et en fin de lactation. Les groupes ont été

systématiquement assignés à trois compléments alimentaires [Régime A: Fourrage de pois cajan produit par hydroponie; Régime B: pois cajan cru et régime C: pois cajan rôti] au lieu de Centrosema pubescens sur trois périodes dans un dispositif croisé 3 x 3. Chaque période d'alimentation a duré deux semaines, suivies d'une semaine de repos pour éviter un effet de report de régime. Les données collectées comprenaient le rendement laitier journalier, les échantillons de lait, le poids à l'intervalle de quinze jours et les coûts. Les échantillons de lait ont été analysés à l'aide d'un analyseur de lait numérique (Milk-Lab Compact). Les échantillons de lait ont été analysés à l'aide d'un analyseur de lait numérique (Lait-Lab Compact). Toutes les données ont été gérées et analysées par le package statistique pour les sciences sociales. Les résultats ont indiqué que pendant les périodes d'adaptation et de repos, le rendement laitier journalier par vache était significativement inférieur ($p < 0,05$) à celui des périodes de traitement. Cependant, les trois régimes de traitement (A, B et C) n'ont pas différé de manière significative ($p > 0,05$) en ce qui concerne le rendement laitier journaliert, la composition du lait (à l'exception des matières grasses) et le gain de poids journalier des vaches. D'autre part, les résultats de l'analyse économique ont montré que la supplémentation des vaches en lactation par le régime A était 26% moins cher que les régimes B et C. En conclusion, le fourrage de pois cajan produit par hydroponie était un complément alimentaire moins cher par rapport aux compléments alimentaires à base de céréales et a eu une influence similaire sur l'amélioration du rendement laitier journalier, de la composition du lait et du gain de poids journalier moyen. Ces résultats suggèrent que l'utilisation de fourrage de pois cajan produit par hydroponie par rapport aux céréales comme compléments alimentaires, peut être une solution de gestion de l'alimentation alternative économiquement rationnelle pour les agriculteurs pendant la longue saison sèche au Malawi.

Mots clés: Compléments alimentaires, moindre coût, Malawi, composition du lait, rendement laitier

Introduction

Dairy production is an important enterprise to Malawian farmers since it is a source of income, food and manure (Lwara, 2013). In Malawi, 97% of the smallholder dairy farmers practice zero grazing, while the rest of the farmers practice either semi-zero grazing or grazing. Banda *et al*. (2011), reported that one of the major challenges faced by smallholder dairy farmers is shortage of quality and adequate feeds and forages, which is acute during the dry season. The existing commercially produced dairy feed is generally expensive and farmers can barely manage. Due to the rising population and competition for resources in Malawi, the smallholder dairy farmers also face additional challenges such as limited amount of land. The challenge of small land ownership leads to low feed production capacity with high dependence on communal areas to source feed or use as a grazing field. Schoenian (2014), described hydroponics which is a method of growing plants without soil by only providing moisture and nutrients that are needed for plants to grow. Under hydroponic production systems, greater yields over a shorter time in a smaller area than conventionally-grown grains are achieved. The system usually consists of a framework of shelves on which metal or plastic trays are stacked. During the growing period, the seeds are kept moist, but

not saturated. They are supplied with moisture and sometimes nutrients, usually via drip or spray irrigation. The holes in the trays are included to facilitate drainage and the seeds sprout within 24 hours and produce a 15-20 cm high grass mat in 5 to 8 days. After the mat is removed from the tray, it can either go into a feed mixer, or be hand-fed to livestock together with the seeds, roots, and grass. The objective of this study was to evaluate the effectiveness of hydroponically produced pigeon pea fodder as a feed supplement against grain-based feed supplements in improving dairy cow performance.

Materials and methods

The experiment was conducted in Malawi at the Lilongwe University of Agriculture and Natural Resources (LUANAR), Bunda Campus, between August and October 2016.

Fodder production. All the pigeon pea grains were locally sourced and part of it used to grow the fodder which was used in this study. The pigeon pea fodder was grown in a modified low cost hydroponic system which was constructed using a greenhouse chamber of 3.0 × 3.0 × 2.6 m in size and was equipped with manual sprayers. It was composed of two units with wooden frame and six wooden shelves each with a length of 300 cm, a width of 114 cm, and a height of 55 cm. Each shelf of the system unit had a capacity to carry 8 plastic trays with a diameter of 60 cm, a radius of 30 cm, and a depth of 6 cm onto which the grain was planted to produce the green fodder. Temperature inside the chamber was moderated to a working temperature of 18^0C to 21^0C and the relative humidity of 70%, by ensuring air circulation through three windows made on the green house. There was provision of 11 – 12 h daylight during the experimental period. Clean seeds of pigeon peas were washed and soaked in tap water containing a sterilizing agent (hydrogen peroxide) for overnight to avoid mouldy sprouts during germination and growth as per recommended (Schoenian, 2014). Thereafter, the seeds were spread in the trays followed by irrigation using a manual sprayer for up to 3 times a day at 6:00 am, 12: 00 pm and 5:00 pm. The fodder was harvested at day 19 and fed directly to the cows.

Experimental design. Six multiparous Holstein-Friesian x Malawi Zebu cross-bred dairy cows were allocated into three groups with each group having a cow in mid and late lactation. The groups were systematically assigned to three diet supplements [Diet A: Hydroponically produced pigeon pea fodder; Diet B: raw pigeon pea and Diet C: roasted pigeon pea] over three periods in a 3 x 3 cross-over design. Each feeding period lasted for two weeks and was followed by a week of resting to avoid a diet carry-over effect. Each cow received 7.5 kg of diet supplement A and 5 kg/cow/day of the grain-based supplements B and C. The difference was based on the low dry matter (DM) content in treatment diet A (15.03 %) as compared to roasted and raw pigeon pea grain diets (B and C), with 91.8 % and 86.1% DM, respectively.

Data collection and analysis. Data collected included daily milk yield, weight at fortnight interval, milk samples on the 7th day of each week during the feeding trial and costs estimates associated with the respective diets. The milk samples were analysed for protein, fat, lactose, salts, total milk solids, solids-non- fat and water content using a digital milk analyser (Milk-Lab Compact, Milk-Lab UK Limited). The data were managed and analysed as a 3 x 3 cross over design in Statistical Package for Social Sciences (SPSS). General Linear Model (GLM) repeated measures test was used to assess the treatments effect over time on milk yield. The effect of the treatment diets on

daily milk yield was assessed using Kruskal-Wallis test since the data were not normally distributed. The influence of the treatment diets on daily average weight gain was assessed using GLM univariate test. In all the statistical models, the diet, group and period variables were included as fixed factor. Chi square test was used to assess the difference between the respective average milk chemical composition of the milk samples analysed to literature values Holstein-Frisians x Malawi Zebu cross-bred cows.

Cost benefit analysis. Gross margin analysis was used to evaluate the feasibility of using hydroponic fodder production system to produce pigeon pea fodder against the conventional system of producing pigeon pea grain (i.e., raw and roasted). Gross margin was defined as the amount remaining after subtracting the cost of producing milk from net sales, and was expressed as a percentage.

Results and discussion

The study was conducted to evaluate how effective and economic hydroponically produced pigeon pea fodder is, as a supplement, in comparison to grain-based supplements (i.e., raw and roasted pigeon pea) in increasing dairy cow milk and weight gain. Results of a Kruskal-Wallis test showed that the daily milk yield production per cow during the one month of adaptation period was significantly ($p < 0.001$) lower (4.52±0.12) than diets A: 5.44 ±0.11; B:5.55±0.12 and C: 5.49±0.14, Table 1. This suggested that the three treatment diet supplements (hydroponic pigeon pea fodder, raw and roasted pigeon pea grains) resulted in increased daily milk yield per cow. There was no significant difference in how diet A, B and C influenced daily milk yield over the entire experimental period ($p = 0.835$).

The lower mean daily milk yields observed before the start of the experiment and during the resting period when cows were supplemented with *Centrosema pubescens* could be related to feed and water consumption influenced by different supplements. Hydroponic fodder already has high moisture content and is known to be highly palatable unlike the dried raw and roasted grain diets which might have triggered more water consumption (Irshad, 2015). There was no significant difference ($p > 0.05$) in milk fat, protein, solids-non-fat and water content when comparing the three-pigeon pea-based diet supplements (i.e. hydroponic

Table 1. Average daily milk production per cow per day (kg) of Holstein-Friesian x Malawi Zebu cross-bred dairy cows

Diet description	Number	Milk yield/cow/day (mean ±S.E.)
Pre-trial: *Centrosema pubescens* supplement	126	4.52±0.12[a]
Diet A: Pigeon pea fodder supplement produced using hydroponic system	110	5.44 ±0.11[b]
Diet B: Raw ground pigeon pea grain supplement	112	5.55±0.12[b]
Diet C: Roasted ground pigeon pea grain supplement	113	5.49±0.14[b]
Resting period	175	5.11±0.10[c]

[a,b,c] *Mean values with different superscripts are significantly different ($p < 0.05$) and S.E. = standard error*

pigeon pea fodder, raw and roasted). However, lactose, salts and total milk solids were significantly lower ($p < 0.05$) for Centrosema pubescens than for the three-pigeon pea-based diet supplements. According to Moran (2005), the udder makes lactose form glucose arriving in the blood. Hence the quantity of glucose arriving at the udder determines how much lactose is produced. The lower mean values for lactose observed in milk during the adaptation period could be because *Centrosema pubescens* provided less glucose which translated into less lactose in milk (4.00±.08) than Diet A: 4.41±.06; B: 4.27±.09; and C: 4.39±.06 (i.e., more glucose in diet, more lactose in milk).

There was no significant difference ($p = 0.340$) in daily weight gain (kg) of cows as a result of supplementing diets A (0.46±0.11), B (0.43±0.10) and C (0.23±0.09). The daily weight gains across all three diets were similar possibly because legumes are rich in energy content (10 to 15 MJ/kg DM for pigeon pea), with protein contents of 15.6 % to 23.5 % DM and fibre, which enhances feed conversion ratio, contributing to weight gain in the cows (Russelle, 2001). Though not significant, means for daily weight gain in cows fed hydroponically produced pigeon pea fodder tended to be high compared to cows fed raw and roasted pigeon pea grains, respectively. This trend is in agreement with Schoenian (2014) who claimed that the sprouting process in a hydroponic fodder production system enhances enzymes to break down storage components into more simple and digestible fractions; for example, starch to sugars, proteins to amino acids, and lipids to free fatty acids. Consequently, there is an increase in fibre and some vitamins by 14 % and a decrease in anti-nutritional factors such as phytic acid in fodder produced hydroponically. This makes hydroponic fodder numerically high in nutritive value than the grains, as previously reported by Arano (2003).

An economic analysis showed that the unit cost associated with the production of hydroponically produced pigeon pea fodder was 26% less costly (MWK 241.47/US$0.57) than that of using conventional production system (MWK 327.79/ US$ 0.77). In general, the total fixed costs associated with hydroponic fodder production system were 50% lower than total fixed costs for conventional method. The total variable costs for producing a kilogram of milk were only 2% higher for hydroponic system (MWK 326.16/ US$ 0.77) than for conventional method (MWK 301.23/ US$ 0.71). This difference was reflected in the total production costs related to conventional method (MWK 102,203.57/ US$ 240) being 1.7 times more expensive than the use of hydroponic fodder (MWK 61,759.85/ US$ 145).

Though hydroponic fodder production is labour intensive (Macaskill, 2017), it was observed that it reduces costs of labour unlike conventional method of fodder production which required more than 1 person to manage. Arano (2003) reported that hydroponic fodder production systems reduced cost of feeding to as low as MWK17,000.00 (US$ 40) a ton, unlike conventionally grown fodder, which included costs of insecticides, fertilizers, machinery as well as cultivation, harvesting and labour; making the total costs 10 times greater than that of hydroponically grown fodder. In this study the hydroponic fodder production system also proved be land use efficient, as only 3 m x 3 m space was used to construct the green house for fodder production. This may be of crucial importance to overcome constraints that come with conventional green fodder production such as small land holdings amongst dairy farmers (Banda *et al.,* 2011). The system is efficient in utilising water as only 2-3 litres of water are required to produce 1 kg of fodder unlike conventional methods which require about 80 litres of water to produce the same amount (Greenfield-Hydroponics, 2014). Other economic benefits not statistically analysed but observed in this study include reduction in growth

period, as the pigeon pea fodder was ready for use within 19 days under hydroponic system compared to four months if it were grown under conventional methods and the system is as well not season dependent (Schoenian, 2014).

Conclusion

The results in this study indicate that the effect of supplementing hydroponically produced pigeon fodder, raw and roasted pigeon pea grains was not different on milk yield, weight gain and milk chemical composition. The daily milk yield production per cow was however significantly influenced with the supplementation when compared to milk production during adaptation and resting periods. Economic analysis demonstrated that use of hydroponic produced fodder as feed supplement was cheaper than using pigeon pea grain-based supplements. These results suggest that using hydroponically produced pigeon pea fodder can be a potential economical alternative feed supplement management solution for farmers especially during the long dry season in Malawi when feed is scarce both in quality and quantity.

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