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Dietary preferences of various hydroponic fodders by West African dwarf rams

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Maize, wheat, millet, and sorghum seeds were sown hydroponically, irrigated using a solution of poultry manure and, harvested at 10 days post-sowing to determine the acceptability of fodders produced by West African dwarf rams (WAD). Three WAD rams with an average weight of 9.5 kg were used for this study, lasting five days. The hydroponic fodders were fed to animals for 30 minutes to determine the intake (consumption), coefficient of preference (CoP) and relative palatability index (RPI). The behaviour of animals to the fodders was studied for three days for two hours with the aid of 8-unit CCTV digital video recorder to determine the time spent on feeding as well as the frequency of movement of the animals on each of the hydroponic fodders. The nutrient contents of the fodders were also carried out and the data generated were subjected to one-way analysis of variance in a completely randomized design. The highest value of crude protein (17.54 %) and lowest acid detergent lignin (4.70 %) were recorded for maize fodder. Significant differences were observed in intake (consumption), CoP and, RPI with the highest values obtained for maize fodder. The CoP was not up to unit (>1) except that of maize fodder. The rams fed maize fodder had greater time spent feeding (15.03 min.) and frequency of movement (12.00) compared to other fodders. This study concluded that maize fodder is more acceptable to animals having the highest quality and preference when compared to other fodders investigated.

Keywords: Behaviour, cereals, hydroponic fodders, preference, sheep

INTRODUCTION

Forage resources, which ruminants primarily rely on, are affordable and cost-effective feed sources most especially during the rainy season (Duguma *et al.,* 2021). Dry periods, mostly in sub-Saharan Africa, are characterized by scarcity and low quality of forages which significantly hinders the growth and productivity of ruminants as a result of low intake and reduced digestibility of the plants (Ouédraogo *et al.,* 2021). Furthermore, inadequate areas of land for forage cultivation and small land holdings for grazing lead to feed scarcity and often cause conflicts between crop farmers and herdsmen. This issue necessitates the search for sustainable methods to ensure year-round quality fodder production in ruminant livestock systems.

Modern practices like hydroponic fodder production can be introduced to mitigate the situation so as to ensure the availability of feed for the animals to improve their productivity. This involves growing plants without soil and is set up in a smaller space such as a greenhouse compared to the conventional growing of fodder crops over large areas of land. Hydroponic systems are cost-effective, require less water and labour and are generally not affected by season, weather conditions and soil type (Barwant and Barwant, 2020; Mahesh *et al.,* 2024). Previous research has shown that hydroponically produced fodders' are high in nutritive quality and easily digestible by animals making them more acceptable to animals being tender with a high proportion of leaves (Girma and Gebremariam, 2018). Fodder produced through hydroponic methods is characterized by its enhanced palatability and superior nutritional value, offering supplementary health advantages to animals (Naik *et al.,* 2015; Mahesh *et al.,* 2024). Compared to plants produced on soil, hydroponic plants have three times the quantity of vitamins and minerals (Barwant and Barwant, 2020). Hydroponic fodders are also low in secondary metabolites such as phytic acid and saponin contents (Lamidi *et al*., 2022).

The approach of animals to the feed offered by the farmers is very important in deciding what type of feed should be made available to animals that will be acceptable to them. The behaviour of animals to feed will vary

between breeds, the maturity of the plants, and the quality of the feed. In this study, the nutrient contents and preference of different hydroponic fodders to West African dwarf rams were evaluated.

MATERIALS AND METHODS

Ethical statement:

The Ethics Committee of the Federal University of Agriculture, Abeokuta, Nigeria, College of Animal Science and Livestock Production approved all experimental and animal management practices (ethical permission number FUNAAB/COLANIM/DRIP/40).

Experimental site:

The experiment was performed at the Screen House of the Pasture Experimental Unit, which is located within the Federal University of Agriculture, Abeokuta Farm, Ogun State, Nigeria (7°58' N, 3°20' E; 75 masl). The mean monthly temperature of 23 ºC and 34.7 ºC was recorded in the screen house.

Preparation of organic nutrient solutions and sowing of seeds:

A kilogram of poultry manure that has been air-dried was dissolved in 10 litres of clean water to serve as an organic nutrient solution (ONS). The mineral composition of the poultry manure nutrient solution used includes nitrogen (2.74 %), phosphorus (1.89 %) and potassium (2.80 %). Cereals such as Premier Oba Super 2 maize cultivar (hybrid maize), millet (local), sorghum white (local) and wheat (local) were bought in Abeokuta town from Farmers' Agro-Allied Store. The test for seed viability was conducted in the laboratory. The screen house surroundings and the planting trays were cleaned and disinfected. The seeds underwent a cleaning process followed by sterilization through immersion in a 20% sodium hypochlorite solution, in accordance with the established procedure of (Al-Karaki and Al-Momani, 2011) for 30 minutes to inhibit the development of mould. The seeds were taken out and thoroughly rinsed with clean water. They were then immersed in water for approximately 8 hours, after which the water was drained from the seeds and they were covered with jute bags and incubated to start the process of growth until about 70% or more of the seeds had sprouted. The seeds were distributed to distinct trays within the screen house according to the specific treatment applied. The sprouted seeds were placed in perforated trays, which were then organized on shelves within the screen house. A sowing rate of 100 grams of maize seeds per tray was employed. The nutrient solution was applied to the seeds in the trays twice per day, in the morning and the evening with each treatment replicated 3 times. Ten days after sowing, all of the sprouted fodders were harvested. Subsequently, the fodders were subjected to drying in a drying cabinet and maintained at 65 °C until a stable weight was achieved.

Experimental design:

The study was arranged in a completely randomized design with four treatments (Premier Oba Super two maize cultivar (hybrid maize), millet, sorghum and wheat replicated three times.

Chemical analysis:

The dried samples were milled and allowed to pass through a 1mm sieve following which the proximate composition was determined according to the procedure of (AOAC, 2000). Fibre fraction concentrations were determined according to the (Van Soest *et al.*, 1991) procedure.

Acceptability study:

Three WAD rams with an average weight of 9.5 kg were used for this study and replicated three times. One kg of the hydroponic fodders (hybrid maize, millet, sorghum and wheat) was offered to each animal per treatment in different feeding troughs, with the addition of two empty troughs at the border ends to prevent the animals from being accustomed to the feed arrangement. The experimental diets were introduced to the animals by 8 am and were allowed to feed for 30 minutes before the animals were allowed to graze for the day. Feed remnants were weighed and deducted from the feed offered to calculate the animals' feed intake. The study was carried out for five days continuously.

One WAD ram each of about 9.5 kg was used for the study per treatment, which was replicated three times. Hydroponics fodders were offered to the animal per treatment in four feeding troughs with two empty troughs at the border ends to prevent the animals from being accustomed to the feed arrangement. The feeds were offered by 8 am before the animals were allowed to graze or offered any feed for the day. One kg of each of the hydroponics fodders was randomly weighed and put in each feed trough. Thirty minutes after the introduction of the feeds to the animals the troughs were removed from the animals and the remaining feeds were weighed to calculate the animals' feed intake. The study was carried out for five days continuously.

The preference for the fodders was calculated as the percentage of the fodders consumed relative to the fodders offered for five days.

$$\% \text{ Consumption} = \frac{\text{Fodder offered} - \text{Fodder remnant}}{\text{Fodder offered}} \times 100 \qquad \text{(Babayemi } et\ al.\text{, 2006)}$$

The preferred fodder was assessed from the coefficient of preference (CoP) value, as the ratio of intake of individual hydroponic fodder and mean intake of all fodders offered (Abegunde *et al.,* 2021). According to (Babayemi *et al.*, 2006), the feed was said to be relatively acceptable if the CoP is greater than the unit (>1).

$$\text{CoP} = \frac{\text{Intake for individual fodder offered}}{\text{Mean intake of all fodder offered}}$$

Daily relative palatability index (RPI) was calculated for the fodder by dividing the consumption values for each fodder by that of the highest value and multiplying by 100 (Abdulrazak *et al.,* 2001).

$$\textbf{The RPI was expressed as follows} = \frac{\textbf{Consumption values for each fodder}}{\textbf{Fodder with the highest consumption value}} \times \mathbf{100}$$

Selection preferences and behaviour using eight digital CCTV camera (Closed Circuit Television) unit study:
The maize, millet, sorghum and wheat hydroponics fodders were placed into different feeding troughs and one ram per replicate was introduced to the feed. The animals were tagged for identification and confined in a feeding yard. This was replicated three times and was repeated for three consecutive days for the preference and behavioural study. The selection preferences and behaviour of the animals fed the experimental diets were monitored in real-time using 8 digital CCTV units. The feeds were offered from 9 am to 11 am. One kg of each of the hydroponic fodders was randomly weighed and put in each feed trough. The feeding troughs were withdrawn after 2 hours.

Animal behavioural study:
The activities of the animals at the fodders were monitored with the aid of 8 digital CCTV unit video recorders and a waterproof camera fitted with a lens. For all the experimental animals, access was given to the fodder every morning of the trial. The recordings were watched on a monitor on the time spent on feeding/occupation time as well as the frequency of movement of the animals on each of the hydroponic fodders.

Data collection:
Each animal was observed continuously for a period of 2 hours daily with the aid of a CCTV video player. Data were collected on the following: time spent on feeding (the number of minutes the animal spent while feeding) and frequency (the total number of the animal movements from a feeding spot to another (either feeding or just perceiving). The time spent by the animals on feeding activity and frequency of feeding/movement were used for the analysis.

Statistical analysis:
The time spent by animals grazing and frequency of grazing were analyzed using the one-way analysis of variance option of the SPSS (IBM SPSS Statistics 23) software. Treatment means were statistically compared using Duncan's Multiple Range Test.

RESULTS

The chemical composition of different hydroponically produced fodders is shown in (Table 1). With the exception of NFC, the chemical composition differs significantly ($p<0.05$). When compared to other fodders, the maize fodder had the highest ($p<0.05$) CP content (17.54%). Millet fodder had the highest fibre fractions (NDF, 46.17 %, ADF, 21.80 %, and ADL, 6.60%) compared to other feeds. The highest value of NDF content was found in millet fodder.

The consumption and coefficient preference values of WAD rams fed the different hydroponic fodders. The consumption, CoP and RPI of the hydroponic fodders varied significantly ($P<0.05$). The consumption ranged from 26.7 to 201 g with the order of preference as maize>wheat>millet>sorghum fodders (Table 2).

Data in (Table 3) shows the effects of feeding hydroponically produced fodders (maize, millet, sorghum and wheat) irrigated with organic nutrient solution (poultry ONS) on the selection preferences and behaviour of West African dwarf rams using CCTV camera (Closed Circuit Television).

The highest significant ($p<0.05$) difference of both time spent on feeding and frequency of movement to a feed by West African dwarf rams was recorded for maize hydroponic fodder above others while time spent on the feeding of wheat fodder was the next. The time spent feeding on maize hydroponic fodder was 15.03min while the least value of 0.63min was spent feeding on sorghum fodder. Maize hydroponic fodder had the significant ($p<0.05$) highest frequency of movement of animals to it while there was no significant ($p>0.05$) difference recorded for other fodders for frequency of movement by individual animals (Table 3).

Table 1. Chemical composition of the different hydroponic fodders

Parameters	Hydroponic fodders				SEM	LSD	*P*-value
	Maize	Millet	Sorghum	Wheat			
Proximate composition (% DM)							
Dry matter	30.38^{a}	23.19^{c}	17.65^{d}	28.56^{b}	0.73	0.5435	<.0001
Crude protein	17.54^{a}	13.04^{c}	14.03^{bc}	15.56^{b}	0.56	1.6189	0.0010
Ether extract	6.93^{a}	4.00^{b}	6.31^{a}	6.09^{a}	0.36	1.023	0.0009
Ash	6.15^{a}	3.25^{b}	7.50^{a}	7.50^{a}	0.58	1.9316	0.0029
Non-fiber carbohydrate	31.88	33.54	32.19	32.01	0.67	4.8508	0.8474
Fiber fractions (% DM)							
Neutral detergent fiber	37.50^{b}	46.17^{a}	40.00^{b}	38.83^{b}	1.12	3.8721	0.0039
Acid detergent fiber	18.01^{c}	21.80^{a}	20.05^{b}	18.50^{bc}	0.49	1.5817	0.0022
Acid detergent lignin	4.70^{d}	6.60^{a}	5.90^{b}	5.20^{c}	0.22	0.2026	<.0001

^{abc}: means on the same row with different superscripts differ significantly (*P*<0.05); SEM= Standard error of mean; FLSD (0.05) = Fisher's least significant difference at 5 % level of probability

Table 2. Acceptability of different hydroponic fodders by West African Dwarf rams

Hydroponic fodder	Consumption (g/day)	Coefficient of Preference	Relatively palatability index (%)
Maize	201^{a}	2.28^{a}	100^{a}
Millet	40.0^{c}	0.45^{c}	19.9^{c}
Sorghum	26.7^{d}	0.30^{d}	13.3^{d}
Wheat	85.3^{b}	0.97^{b}	42.5^{b}
SEM	17.7	0.20	8.81
***P*-value**	<.0001	<.0001	<.0001
LSD	2.6575	0.0375	0.8646

$^{a-c}$ means on the same row with different superscripts are significantly (*P*<0.05) different; SEM=standard error of mean; FLSD (0.05) = Fisher's least significant difference at 5 % level of probability

Table 3. Time spent on feeding and frequency of movement to hydroponic fodders by West African dwarf rams

Hydroponic fodders	Time spent feeding (Minutes)	Frequency of movement
Maize	15.03^{a}	12.00^{a}
Millet	1.31^{c}	6.67^{b}
Sorghum	0.63^{c}	5.00^{b}
Wheat	5.09^{b}	7.00^{b}
SEM	1.81	0.84
FLSD (0.05)	3.8658	2.1741
***P*-value**	0.000	0.000

$^{a-c}$ means on the same row with different superscripts are significantly (*P*<0.05) different; SEM= standard error of mean; FLSD (0.05) = Fisher's least significant difference at 5 % level of probability

DISCUSSION

Maize fodder had the highest CP content (17.50 %) above other fodders and the CP contents in this study are higher than the minimum recommended range of 7.0 - 8.0 % for the functioning of rumen microorganisms and 11.00-13.00 % which can provide ruminants with enough protein for maintenance and moderate growth (NRC, 1981). This indicates that the fodders contain enough nitrogen required by the microorganism to enable them to easily digest dietary fibre, which will result in higher voluntary feed intake (Tilahun *et al.,* 2017). The CP and EE contents were higher than 16.36 % and 4.41 % reported by (Lamidi *et al.*, 2022) for hydroponically produced maize hybrid. The ash content of wheat (2.6 %) reported by (Harerimana *et al.*, 2023) was lower than the 7.5 % recorded in this study. The CP of millet obtained in this study was slightly lower than the 15.94 % reported by (Silva *et al.*, 2020). The NDF content is similar to 36.28 % for maize var. BH540 reported by (Getachew *et al.*, 2020). This implied that both the intake and digestibility of the fodders by animals will not be hindered since the NDF values are below 65 % (Eastridge, 2006). The amount of ADF indicates digestibility; the higher the ADF, the less digestible and energy-dense

the feed is (McDonald *et al.,* 1991). The ADF content of the maize fodder obtained in this study is similar to the 18.57 % reported by (Adeyemi *et al.,* 2021). There are various reasons why the results could differ which include varieties of cereals used as well as different solutions used to irrigate the plants. Lower NDF values below the critical limit (60-65 %) (Muia, 2000) were recorded for all the fodders. High consumption could be attributed to the palatability of the feed such as taste, odour and texture which influence the intake by the animal. The acceptability was highest for maize fodder with values of 2.28 and 100.00 % for CoP and RPI, respectively. The results further showed that the CoP values of the fodders were less than 1, except that of maize fodder showing that it was preferred over others. This could be due to its high CP with low NDF and ADF contents, which make the fodder easily digestible. An earlier study has reported that the preference and subsequent high intake of a feedstuff could be as a result of the presence of phytochemicals in the feed which eventually influences the voluntary intake, of the animal (s) (Obour *et al.,* 2015). Animals relish fodders with high contents of leaves. Obour *et al.*, (2015) reported that feeds with RPI >60% are most acceptable, followed by those with 35-55% as medium, while those with <25% have low acceptability. In this study, maize fodder was ranked as the most preferable and most acceptable, wheat as medium while sorghum and millet fodders had low acceptability.

Previous research has shown the amount of time spent by animals while grazing can be influenced due to some factors such as plant species, availability of feed, and the nutritional content of the feed (Mohammed *et al*., 2020). Differences exhibited by animals to different hydroponic fodders offered showed their behaviour to different feeds offered at a particular time. The findings of this investigation showed that the selection of maize over all other fodders could mainly be a result of the animal's preference for maize fodder. This preference could have been necessitated by the high nutritive quality of maize fodder which makes the animals spend more time on the fodder compared to other hydroponic fodders. The lushness and palatability of the maize fodder as much as how it is relished by the animal could have attracted the animal to it above others. The longer time spent for rams fed maize fodder might also be due to the short time spent on ruminating and long time for standing. This agrees with the findings of (Khoso *et al.*, 2020) who reported a longer time standing for sheep fed maize and millet with higher consumption (intake) compared to sheep fed sorghum which has lower intake and this might be attributed to short time standing. Previous research has shown that the quantity of fodders offered to animals could improve their feeding rate and rumination which influence their behaviour (Khoso *et al.,* 2020). Longer time spent and frequency of movement for rams fed maize fodder could also be due to taste and appearance, and higher proportion of leaf. (Cardoso *et al.,* 2020) reported that the selection of leaves and behaviour of animals grazing tropical pasture sward was affected by leaf bulk density, the height of the sward and the total herbage mass. The preferential selection of maize fodder by the WAD rams in this study could be attributed to the nutritive quality of the maize hydroponic fodder.

CONCLUSION

The hydroponic fodders were high in nutritive value especially that of maize fodder which had the highest crude protein and lowest acid detergent lignin. The maize fodder had better acceptability by the rams, with the highest time spent feeding and frequency of movement of animals to it when compared with other fodders. Therefore, this can be used by farmers as a supplement to low quality feed that is usually available during periods of feed deficit to sustain ruminants.

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REFERENCES

Abdulrazak, S. A., Nyangaga, J., & Fujihara, T. (2001). Relative palatability to sheep of some browse species; *in sacco* degradability and *in vitro* gas production characteristics. *Asian-Aust. Journal of Animal Science*, 14(11), 1580-1584.

Abegunde, T. O., Babalola, S.O., Adeoye, B. T., Usman, A. O., & Akinyemi, O. M. (2021). Nutritive value and preference of guinea-Grass ensiled with or without additive by West African Dwarf (WAD) goats. *Tropical Animal Science Journal*, *44*(2), 173-182.

Adeyemi, T. A., Adeoye, S. A., Ogunyemi, T. J., Adedeji, E. A., Oluyemi, B., & Ojo, V. O. A. (2021). Comparisons of nutrient solutions from organic and chemical fertilizer sources on herbage yield and quality of hydroponically produced maize fodder. *Journal of Plant Nutrition*, 44(9), 1258-1267.

Al-Karaki, G. N., & Al-Momani, N. (2011). *Evaluation of Some Barley Cultivars for Green Fodder Production and Water Use Efficiency Under Hydroponic Conditions\Jordan Journal of Agricultural Sciences.-2011, 7,(3), 448-457*. University of Jordan.

AOAC. (2000). Official methods of analysis, 15th edition. Association of Official Analytical Chemists, Washington DC. USA.

Babayemi, O. J., Bamikole, M. A., & Omoloja, A. B. (2006). Evaluation of nutritive value and free choice intake of two aquatic weeds (*Nephrolepis biserrata* and *Spirodela polyrhiza*) by West African dwarf goats. *Tropical and Subtropical Agroecosystem* 6, 15-21

Barwant, M., & Barwant, K. (2020). Comparative study of artificial fodder production (Hydroponic) and its benefits. *International Journal of Innovative Science and Research Technology***,** 5, 106-111.

Cardoso, A. S., Barbero, R. P., Romanzini, E. P., Teobaldo, R. W., Ongaratto, F., Fernandes, M. H., Ruggieri, A. C., & Reis, R. A. (2020). Intensification: A key strategy to achieve great animal and environmental beef cattle production sustainability in *Brachiaria* grasslands. *Sustainability*, *12*, 6656.

Duguma, B., & Janssens, G. P. (2021). Assessment of livestock feed resources and coping strategies with dry season feed scarcity in mixed crop–livestock farming systems around the gilgel gibe catchment, Southwest Ethiopia. *Sustainability*, *13*(19), 10713.

Eastridge, M. L. (2006). Major advances in applied dairy cattle nutrition. *Journal of Dairy Science*, 89, 1311-1323.

Getachew, A., Mengistu, U., Getachew, A., & Getnet, A. (2020). Effect of variety and seed rate on hydroponic maize fodder biomass yield, chemical composition, and water use efficiency. *Biotechnology in Animal Husbandry,* 36 (1), 87-100.

Girma, F., & Gebremariam, B. (2018). Review on hydroponic feed value to livestock production. *Journal of Scientific and Innovative Research*, 7(4), 106-109.

Harerimana, T., Hatungimana, E., d'Andre Hirwa, C., & Niyireba, R. T. (2023). Effect of hydroponic wheat fodder supplementation on dry matter intake and growth performances of piglets. *Scientific African*, 19, 1-7.

Khoso, A. N., Soomro, J., Marghazani, I., Kakar, B., Baloch, A. H., Brohi, S. A., & Arain, M. A. (2020). Comparative Investigation of Feeding Habits and Apparent Digestibility of Maize, Millet and Sorghum. Pakistan Journal of Agricultural Research, 33(3), 433-439.

Lamidi, A. A., Ingweye, J. N., & Mene, L. (2022). Influence of seed varieties and harvesting regimes on growth indices, yields and nutritional values of hydroponics maize fodder. *Nigerian Journal of Animal Science*, *24*(2), 221-230.

Mahesh, M. S., Chaudhary, S. K., Tewari, D., & Dutta, N. (2024). Hydroponic Forage for Ruminant Feeding: A Comprehensive Review. *Animal Nutrition and Feed Technology* 24: 441-459.

McDonald, P., Edwards, R. A., & Greenhalgh, J. E. D. (1991). Animal nutrition. 4th Ed. LS & T. USA.

Mohammed, A. S., Animut, G., Urge, M., & Assefa, G. (2020). Grazing behavior, dietary value and performance of sheep, goats, cattle and camels co-grazing range with mixed species of grazing and browsing plants. *Veterinary and Animal Science*, *10*, 100154.

Muia, J. M. K. (2000). Use of Napier grass (*Pennisetum purpureum*) to improve smallholder milk production in Kenya. PhD. Thesis. Wageningen Agricultural University. The Netherlands

Naik, P. K., Swain, B. K., & Singh, N. P. (2015). Hydroponics: its feasibility as an alternative to cultivated forages. In: Proc. 9th Biennial Animal Nutrition Association Conference on 'Eco-responsive Feeding and Nutrition: Linking Livestock and Livelihood' held at Guwahati, India, January 22-24, 2015, 74-87

NRC. (1981). National Research Council. Nutrient Requirements of Goats: Angora, Dairy and Meat in Temperate and Tropical Countries. National Academies Press, Washington D. C., USA, ISBN-13:9780309031851, 91

Obour, R., Oppong, S. K., & Abebrese, I. K. (2015). Forage palatability of *Broussonetia papyrifera* an invasive species in Ghana: Relative preference and palatability by sheep and goats. *Journal of Energy and Natural Resource Management,* 2(2), 63-70.

Ouédraogo, K., Zaré, A., Korbéogo, G., Ouédraogo, O., & Linstädter, A. (2021). Resilience strategies of West African pastoralists in response to scarce forage resources. *Pastoralism*, *11*(1), 16.

Silva, R. M. D., Taveira, R. Z., Restle, J., Fabricio, E. D. A., Camera, A., Maysonnave, G. S., ... & Vaz, F. N. (2020). Economic analysis of the risk of replacing corn grains (*Zea mays*) with pearl millet grains (Pennisetum glaucum) in the diet of feedlot cattle. *Ciência Rural*, *50*(3), e20190443.

Tilahun, G., Asmare, B., & Mekuriaw, Y. (2017). Effects of harvesting age and spacing on plant characteristics, chemical composition and yield of desho grass (*Pennisetum pedicellatum* Trin.) in the highlands of Ethiopia. *Tropical Grasslands-Forrajes Tropicales*, 5(2), 77 – 84.

Van Soest, P. V., Robertson, J. B., & Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science*, *74*(10), 3583-3597.