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Understanding the dairy cattle feeding strategies, awareness and perceptions of smallholder farmers on hydroponic fodder technology, Kibaha District, Tanzania

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Abstract

The role of hydroponic fodder technology (HFT) on producing nutritious green feed supplements for enhancing the productivity of dairy cattle has been mostly demonstrated in developed countries. Despite the benefits of HFT, its adoption is yet to be popular among smallholder and landless dairy farmers in Tanzania. Here, we assess the feeding strategies, awareness, and opinions of small-scale dairy farmers on HFT. The study was a cross-sectional survey. We found that farmers practiced zero-grazing systems and none practiced on-farm pasture production. The average milk yields in the wet season were higher than milk produced in the dry season. The access to concentrates for supplementing the poor roughages was constrained by unreliable quality, dry season scarcity, and off-season high prices. The majority of farmers were unfamiliar with HFT and few farmers who have adopted the technology were constrained by agronomic problems. The farmer's decision to adopt the HFT or not was relatively based on additional income versus the cost of inputs. Generally, we conclude that HFT adoption is still poor or nonexistent in most of the small-scale dairy farming systems of Tanzania. Further research on potential solutions for overcoming the barriers towards HFT adoption for sustainable smallholder dairy production in peri-urban areas is recommended.

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Introduction

In East Africa, smallholder dairy farming has been noted to grow and has great potential for contributing to the economic development of the region. The demand for livestock products such as milk and meat is reasonably anticipated to increase because of the increase in population, urbanization, and per capita income (Paul *et al.,* 2020). In developing countries, smallholder dairy production is mostly found in densely populated low-income urban and peri-urban communities where milk demand is high (Franzel and Wambugu, 2007).

About 33 to 67% of the land in Tanzania is either semi-arid or arid due to temporal and spatial distribution of low and erratic rainfall coupled with high evapotranspiration rates (Mongi *et al.,* 2010). According to Kurwijila *et al.* (2012), most of the improved dairy cattle are kept by 37% of total rural households who are concentrated in the cooler highland regions with subtropical climates such as Kilimanjaro, Arusha, Tanga, and Mbeya Regions. The communal grazing land in Tanzania is shrinking due to rapid human population growth. This implies that the future of milk production in the country will rely on intensive zero-grazing systems (Kavana *et al.,* 2005; Swai *et al.,* 2011).

The basal feeds for confined animals under zero-grazing systems are mainly obtained from the crop residues such as maize, bean-stover, and banana leaves or natural grasses (*Wambugu et al.,* 2011). The availability of on-farm green fodder has been constrained by frequent droughts and shortages of water for irrigation (Swai *et al.,* 2011). Also, most smallholder dairy farmers do not grow pasture due to several reasons including water shortages, scarcity of arable lands, scarcity of quality pasture seeds, and events of natural calamities such as wildfires (Sewando *et al.,* 2016; Salo, 2019).

To overcome the severe shortage of dairy cattle feed supplements, the usage of green fodder produced through the hydroponic technology is advocated. The technology involves growing plants in less water or nutrient-rich solutions without soil preferably under the greenhouse environment for a few days to allow the growth of green foliage and root carpet commonly called hydroponic fodder (Bakshi *et al.,* 2017). The hydroponically grown green fodder resembles a mat commonly of 20-30 cm height including biomass of roots, seeds, and plants (Naik *et al.,* 2015). Considering the variations in season and climatic condition of the locality or region., the production of 1kg of green fodder of barley, alfalfa, and Rhodes grass has been reported to involve about 73, 85, and 160 liters of water in field condition respectively while the same amount of green fodder of each fodder-product involving about 1.5-2 liters of water under hydroponic technology (Kammar *et al.,* 2019). The HFT has been recommended in arid and semiarid regions reasonably to allow season-less growing capability, grow a high number of plants in a limited space, increase water efficiency, reduce the cost of production, manpower, and the needs for soil as currently being practiced in traditional farming methods (Agius *et al.,* 2019; Nadu, 2019). The HFT has also the benefit of eliminating the soil-borne pests, weeds, and diseases (Du Plooy, 2012). Nevertheless, it has been indicated that hydroponic fodder increases the digestibility of the nutrients in poor roughages based rations and contributes towards the increase in milk production by 8 to 13% (Naik *et al.,* 2015; Naik *et al.,* 2016). The HFT has been of great potential for improving livestock production including poultry, dairy cows, pigs, and small ruminant species. Successful trials have been reported on cereal legumes such as maize, barley, and oats. Among the leading countries in the adoption of the HFT are Israel, the United Kingdom, Australia, Netherlands, Spain and Canada (Murali *et al.,* 2011). According to Schaible *et al.* 2015, the adoption of HFT by smallholder farmers may result in the good management of the ecosystem, environmental conservation, and good business. In Africa, HFT has been mainly adopted in South Africa and to a limited extent in East African countries in particular Kenya (Sydow, 2010; Njima, 2016). Currently, the studies in Tanzania which investigate how the innovations of HFT are being adopted by small-scale dairy farmers and how farmers perceive the corresponding benefits and challenges are limited. The overall aim of this study was to assess dairy cattle feeding strategies, awareness, and perceptions on HFT among the smallholder farmers in Kibaha district, Coastal Tanzania. This information was needed and thought vital for informing the public and private stakeholders interested in sustainable dairy production in Tanzania.

Materials and methods

Study area

The baseline study was conducted in the Kibaha district located approximately 40 kilometers west of Dar es Salaam city which is the largest commercial city of Tanzania. Kibaha is situated between latitude 060 46'S and longitude 380 55' E, Coastal Tanzania (Fig. 1).

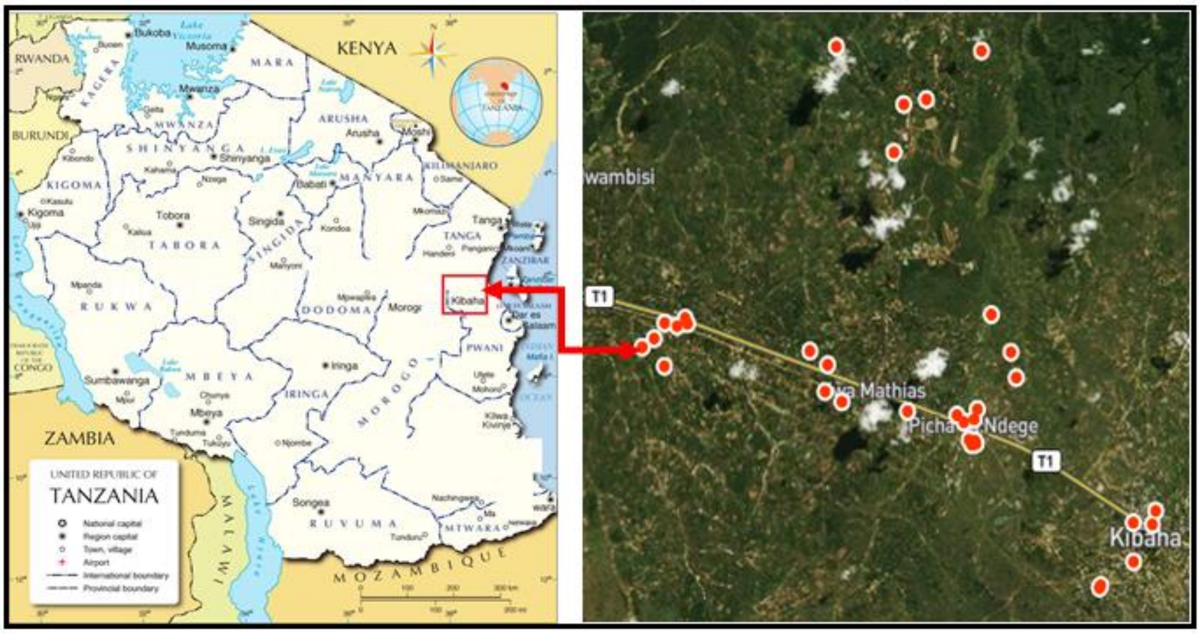

Fig. 1. Map of Tanzania showing the study site.

Kibaha District has a tropical sub-humid climate and with a bimodal type of rainfall whereby short rains fall between October and December and long rain between mid-March and May. The hottest months are January to mid- March while the coolest months are June and July.

Data collection

The study used purposive sampling to analyze the awareness of hydroponic technology among dairy farmers at the study site. The cross-sectional survey, especially on the status of a dairy farmer, traditional feeding practices, and farmer's awareness on fodder production by hydroponic production and future challenges and opportunities, were collected using a structured questionnaire that was uploaded in android smartphone and tablets that were installed with Geographical Open Data Kit (GeoODK) applications. Kibaha district was selected as a base of dairy farmers in the Pwani region. The selection involved a multistage random sampling procedure to select the wards to be covered by the study in Kibaha District. To ensure a good representation of dairy farmers in the study area, seven wards out of fourteen were selected as units of sampling. These units were selected on the bases of a large number of dairy cows and farmers who conducted mostly zero-grazing.

The wards included Kongowe, Maili Moja, Mkuza, Msangani, Picha ya Ndege, Tumbi, and Sofu. The final sample of 36 was drawn randomly from the study areas using Yamane (1967) formula. This formula assumed 95% confidence level and precision of 0.05; $n = N/ [1+Ne^2]$, where n is the sample size, N is the population size dairy farmers particularly under zero-grazing and e is the level of precision.

Focus group discussion

To validate the findings of the baseline survey, the focus group discussion was conducted in each of the selected wards. Each ward included 20 key informants who ware experienced and knowledgeable on livestock production including poultry, pigs, and small ruminant species.

The discussion intended to capture the feeding practices, awareness, and opinions of the small-scale farmers especially on worries, interests, and possible drivers that may accelerate the adoption of hydroponic fodder production technology at small scale-dairy farming in peri-urban areas.

Analysis

The Statistical Package for Social Sciences (SPSS), IBM version 20 was used to analyze the data for exploratory variables used to describe the general dairy farming system. Moreover, The Chi-square test under IBM SPSS 20 was used to test whether there was a significant difference between dry and wet season milk yields and the involvement of males and females in dairy feeding activities at a 95% confidence interval.

Results

Description of the current small-dairy farming system

The survey on dairy farmers shown that the respondents were mostly male (69%) while the lower number being noted to women (31%). Both males and females were mostly found with the primary level of education (Table 1). The percent of dairy-farmers who kept the hybrid dairy cows that were higher for Friesian followed by Jersey and Holstein while few dairy farmers were found to keep the local breed of Zebu and Mpwapwa and Boran (Table 1).

Table 1. A current typology of small-daily farming system (%).

Category of variable	Description	Sub-description	(%) of respondents
A	Level of education of the respondent	Primary education	80.0
		Secondary education	14.0
		Bachelor degree	6.0
		MSc. degree	0.0
		Ph.D. degree	0.0
B	Breed kept by respondent	Friesian	27.0
		Jersey	25.0
		Ayrshire	22.0
		Holstein	15.0
		Mpwapwa	5.0
		Zebu	5.0
		Boran	0.0
C	Concentrates given to dairy cows	Maize bran	40.5
		Sunflower seed cake	24.3
		Minerals and vitamins	18.9
		Molasses	10.8
		Cottonseed cake	5.4
D	Method of feeding	Zero-grazing	83.0
		Extensive-grazing	12.0
		Semi intensive-grazing	5.0
E	The key purpose of keeping a dairy cow	Income	39.0
		Milk for family consumption	33.0
		Manure	24.0
		Biogas	4.0

Considering the category variables of B, C, D, and E, each farmer was allowed to respond to multiple options of a corresponding category.

The higher percentage of dairy-farmers were found to feed the dairy cows with the concentrate of maize-bran compared to farmers who fed the dairy-cows with the sunflower cake, mineral and vitamins, molasses, and cottonseed cake (Table 1). The main method of keeping the dairy cows was zero-grazing followed by extensive-grazing and semi intensive-grazing method. Based on Table 1, it was also found that the main reason behind farmers to keep the dairy cows was earning income and getting milk for their consumption while manure and biogas products being given low priority by the farmers. Furthermore, the household indicated to keep 1 or 2 dairy cows. Such dairy cow(s) may have a status of being pregnant or lactating (Table 2). In the case of lactating cows, the higher percent of farmers indicated to hold the dairy cow in a stage of 1-3 months or 4-7 months of lactation (Table 2).

Table 2. Availability of pregnant cows, lactating cows, and cow's lactation stage.

Variable for the cow production status	Number of cows	Number of Farmers	(%) of farmers
Pregnant cows	1.0	9	52.9
	2.0	6	35.3
	3.0	1	5.9
	20.0	1	5.9
	Total	17	100
Number of lactating cows	1.0	19	44.2
	2.0	13	30.2
	3.0	5	11.6
	5.0	3	7.0
	7.0	2	4.7
	8.0	1	2.3
	Total	43	100
Stage of lactation	1-3 Months	19	44.2
	4-7 Months	18	41.9
	> 7 Months	6	14.0
	Total	43	100

Each farmer was allowed to respond to multiple options for a given variable indicating the cow production status.

Production of dairy cattle under wet and dry season condition

Considering Table 3, the average number of milked cows during the wet season (did not reasonably differ from the average number of milked cows during the dry season (p-value =0.34, α=0.5). However, the average daily milk (liters) per cow during the wet season was found to differ significantly from that of the dry season (P-value = 0.001, α=0.5).

Table 3. Effects of the wet season (November to May) and dry season (June to October) on the number of milked cows and milk production.

	The average number of milked cows		Average daily milk (liters/ cow/day)	
	Wet season	Dry season	Wet season	Dry season
Average	2.7 (0.55)	2.5(0.45)	6.2 (0.35)	4.4(0.27)
Sign. (2-Tailed)	++		**	

++ = Not Different (p-value =0.34, α=0.05) and ** = Different (p-value = 0.001, α=0.05), the numbers outside the bracket indicate the mean and the numbers inside the bracket indicate the standard deviation.

Current farmer's feeding strategies in the wet and dry season

The results shown in Fig. 2 indicate that zero-grazing was the most dominant grazing technique employed by the interviewed farmers (84%) during both wet season and dry season. The average number of farmers who used the extensive grazing method was nearly equal to the average number of farmers who practiced the semi-intensive grazing method. The results indicated also that the percentage of farmers who practiced intensive-grazing and semi-intensive grazing did not change their feeding practices based on either wet season or dry season.

Table 4. Involvement of female and male in feeding method during the dry and wet season.

		Feed method			Total	Chi(χ^2),*p*
Season		Zero grazing	Semi-Intensive grazing	Extensive grazing		
Dry season	Female	9(30.0)	2 (50.0)	0 (0.0)	11	
	Male	21(70.0)	2(50.0)	2(100)	25	(1.597), 0.450
	Total	30 (100)	4 (100)	2(100)	36	
Wet Season	Female	8(28.6)	2(40.0)	1(33.3)	11	
	Male	20(71.4)	3(60.0)	2(66.7)	25	(0.273), 0.872
	Total	30(100)	5(100)	3(100%)	36	

For columns of Zero-grazing, Semi-intensive-grazing, and Extensive-grazing, the numbers outside the bracket = numbers of farmers and numbers inside the bracket indicate the percentage of farmers.

Participation of female and males on feeding method during the dry and wet season

Considering the participation of the males and females on feeding practices during the wet season and dry season (Table 4), the number of males who conducted the zero-grazing feeding method during the wet and dry season was higher than the number of females. Both male and female dairy farmers indicated little interest to conduct extensive and semi-intensive grazing methods in the wet and dry season. The proportion of females and males in opting the extensive grazing was similar. There was no difference between female and male farmers who opted to use any of the method neither in dry season (Chi (χ^2) =1.597, p= 0.45 α =0.05) nor in wet season (Chi (χ^2) =0.273, p= 0.872 α =0.05). Besides, there was no any farmer who expressed to set aside an area to grow pasture under irrigation.

Table 5. Farmer's awareness and adoption of hydroponic fodder production.

	% of farmer’s responses (n =36)		Total (%)
The aspect of hydroponic fodder production	Yes (%)	No (%)	
Awareness on hydroponic fodder	16.7	83.3	100
Adoption of hydroponic fodder production technique	5.6	94.4	100

Major challenges for dairy cattle feeding

The prioritization of feeding problems (Fig. 3) was found in three groups of animal fodder 19 (53%) and feed concentrates 15 (42%) and others.

The fodders were expressed in terms of high distance to fodder areas, high cost of fodder transportation, and accessing of good quality fodder especially in dry season while the concentrates were expressed based on cost, quality, and availability regardless of the type of season. Others included the rejection of either fodder or concentrates by animals and lack of innocent hired casual labours for feeding animals.

Considering Fig. 4, about 58.3% did not express the use of direct cash to purchase the fodder. The fodder was collected by either family members or casual labour who were paid at the end of the month due to a combination of works. It was further noted that about 10 (27.8%) of the farmers relied on the fodder diet with or without routine supplements. Besides, we noted that farmers did not feed forage and concentrates based on animal weight and physiological conditions.

Table 6. Farmer's opinion on hydroponic fodder production technique.

Aspects	Description	Decision		Total
		Yes (%)	No (%)	No (%)
Positive response	Interest on hydroponic fodder production	36 (100.0)	0 (0.0)	36 (100)
	Need of training and dissemination	36 (100.0)	0 (0.0)	36 (100)
	Space for installation of production facility	36(100.0)	0 (0.0)	36(100)
	Accessibility of water for irrigation	36(100.0)	0 (0.0)	36(100)
Doubts	Availability fodder quality seeds and respective seed cost	23 (63.9)	13(36.1)	36 (100)
	Cost of inorganic nutrients and availability	31(86.1)	5 (13.9)	36 (100)
	The need for a permanent structure such as greenhouse	27(75.0)	9 (25.0)	36(100)
	Rejection and acceptability of livestock animals	19 (52.8)	17 (47.2)	36 (100)
	Low fodder production under organic nutrients	26 (72.2)	10 (27.8)	36 (100)
	Cyanide effect of tenderer plant fodders	11 (30.6)	25 (69.4)	36(100)
	Low nutritive value of fodder due to the use of inorganic fertilizers	32 (88.9)	4 (11.1)	36 (100)
	Producing hydroponic fodder at large scale	17 (47.2)	19 (52.8)	36 (100)

Numbers outside the bracket = numbers of farmers, and numbers inside the bracket = percentage of farmers.

Main concentrates and average use

Following the concept of a farmer using more than one feed supplement as indicated in Table 1, the maize bran was mentioned as the main supplement followed by sunflower seed cake in the supplementary ration. The minerals and vitamins scored the third position while the cottonseed cake and molasses supplements indicated lower scores among the mentioned concentrates. Most of the farmers (10-30%) supplemented their cows with 2 to 5kg per day when excluding the mineral concentrates (Fig. 5). Informal discussion with the farmers revealed that less than 2 Kg/cow/day is ineffective towards stimulating increased milk outlet. While over 5 Kg was thought unpractical due to the high prices of the concentrates, the price of these concentrates was found to be between \$0.35 and \$ 0.6 per kilogram.

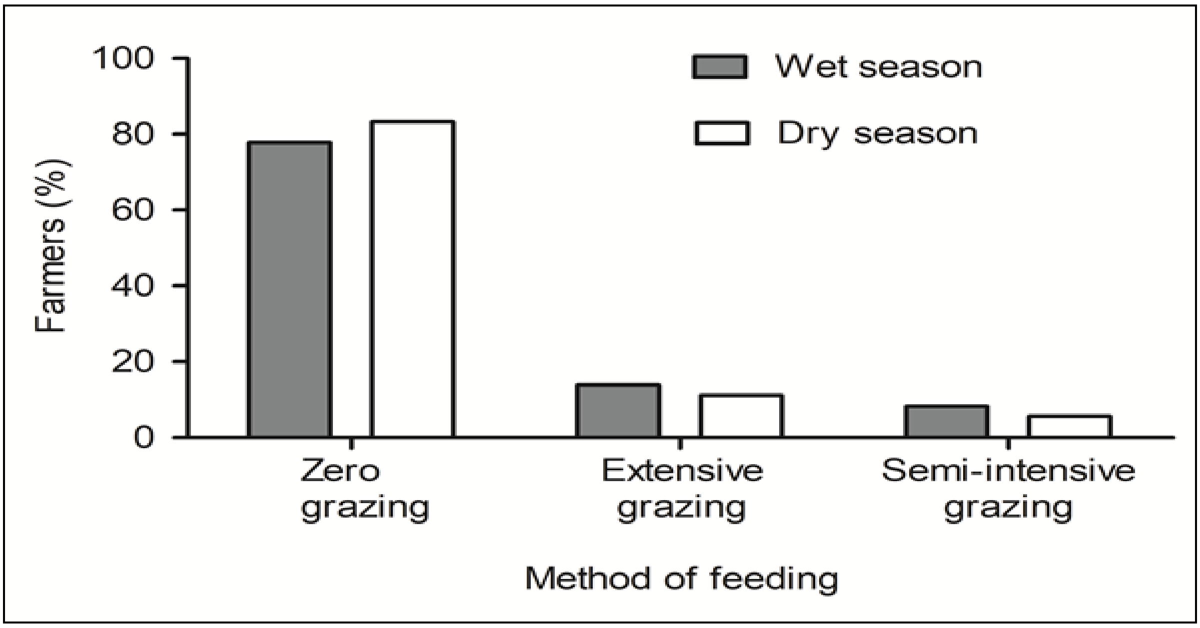

Fig. 2. Percentage of the method of feeding under dry and wet season.

Awareness and adoption of hydroponic fodder production

Based on Table 5, it was realized that the majority of dairy livestock farmers were unaware of the hydroponic fodder production technique. Few farmers (16.7%) were found to be familiar with HPFT and declared that the major source of information on HPFT was through the internet and radio. On another hand, the percentage of adoption was lower among all interviewed dairy livestock farmers.

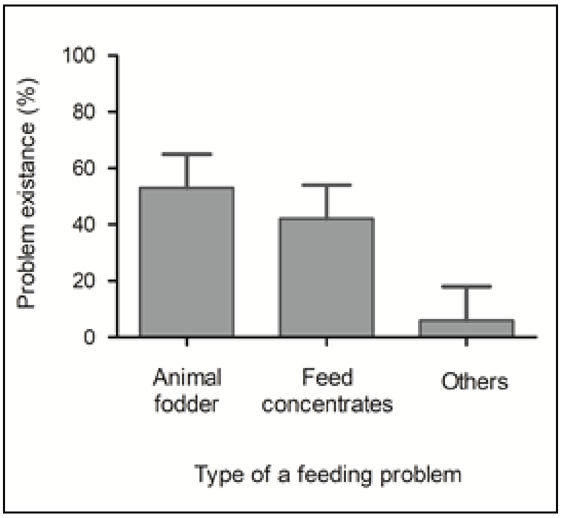

Fig. 3. Lack of adequate animal feeds for dairy farmers.

Perceptions of farmers on hydroponic technology

Based on Table 6, most of the farmers 26 (72.2%) and 17 (47.2%) expressed the concerns on the ability of organic nutrients to produce the hydroponic fodder and the possibility of producing it at a large scale respectively. On the other hand, farmers expressed concern about the availability of fodder quality seeds and respective seed costs. Farmers 27(75%) indicated the worries on the need for a permanent structure such as a greenhouse.

Discussion

Production of dairy cattle under wet and dry season condition

We found that the average number of milked cows during the wet season did not reasonably differ from the average number of milked cows during the dry season. The average daily milk (liters) per cow during the wet season was lower than that of the dry season. Similar findings were observed in Paul *et al.* 2020. The effect on milk yield may be due to lack of fodder during the prolonged droughts that affect the grazing land, decrease the water availability for livestock, and sometimes leading to animal death (Sewando *et al.,* 2016). Moreover, the distance for searching the fodder, quantity, and quality of natural pasture has been reported to exacerbate the milk quantity during dry and short rain periods (Epaphras *et al.,* 2004). Lack of land for fodder cultivation, labor requirement, and high cost of fertilization has been considered as a source of low milk production for such small farmers (MOA, 2014). Rodriguez *et al.* 2004 suggest the growing hydroponics fodder as the control for such livestock feed diets and improve performance

Feeding strategies in the wet and dry season

The zero-grazing method was the most dominant grazing technique employed by the interviewed farmers during both the wet season and dry season. The same findings were observed in Kavana *et al.* (2005). The zero-grazing farms were found to perform poorly under ecological and economic point views due to the use of low efficient concentrates and byproducts as suggested in Meul *et al.* (2012). Recovering on the feeding of inadequate and low quality concentrates for optimizing cows' rations with more forage would be supported by the use of hydroponic fodder. Such kind of fodder would be easily accessed annually under the household level through the use of hydroponic fodder production technology. Moreover, we found 11-14% of farmers to engage with extensive grazing in dry and wet seasons. However, according to Bohm *et al.* (2009); Keyyu *et al.* (2006), this type of grazing practice has been noted to lead to higher rates of inter-herd contact and disease transmission than under other management practices. The reason behind such percent of dairy livestock farmers to engage in extensive grazing methods could be the lack of adequate fodder to feed the dairy cows during zero-grazing. Furthermore, the number of males was higher than the number of females under the zero-grazing method during the dry and wet season. The reason for the little number of females to engage in the keeping of dairy cows could be the challenges associated with feeding the livestock such as searching for green fodder, transportation of forage from a long distant area, and accessibility of quality feed concentrates.

Major challenges for dairy cattle feeding

The prioritization of feeding problems was found especially on animal fodder and feed concentrates. We found the forage to be obtained from a long-distance especially during the dry season. The same findings were reported in Gillah *et al.* (2013) who found farmers in nearby peri-urban areas of Dar-es-Salaam to cover about 14.7km in searching for forage mainly using vehicles and bicycles/heads. The availability of forage during the dry season was also associated with the high cost of transportation and low-quality conditions. The access to the improved variety of planted forages, crop-residues, and high-energy concentrates was limited.

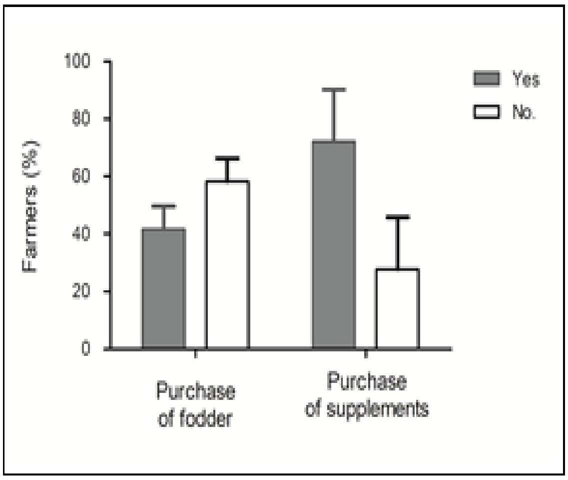

Fig. 4. Purchase of fodder and animal supplements.

On another hand, the energy and protein-rich concentrates were observed as a second major problem facing farmers due to scarcity, lack of good quality, and high price. Similar results were reported in Meul *et al.* (2012). Other problems included the disease of animals, labours for feeding animals, and lack of enough drinking-water for animals were observed to contribute about 6% of the hindrance.

Moreover, most of the farmers (58.3%) did not express the use of direct cash to buy the fodder. The forages were collected either by family members or casual labour. It was further noted that about 10 (27.8%) of the farmers relied on the fodder diet with or without routine supplements. However, the amount of forage that is brought to livestock is often limited due to forage availability and relatively limited grazing land (Keyyu *et al.,* 2006; Caudell *et al.,* 2017). Besides, farmers did not feed forage and concentrate based on the animal's weight and physiological conditions. For instance, most of the farmers expressed to feed about 2kg/cow/day without considering any of the animal's weight and the physiological condition of the specific cow. The reason for feeding the dairy cows without considering the physiological condition of the animal could not only be attributed to a lack of adequate capital but also the behavior due to traditional feeding and little agricultural extension services.

Awareness and adoption of hydroponic fodder production technology

Although hydroponic fodder has been advertised and perceived by some producers as a solution to drought, the majority of the respondents were found unaware of the hydroponic fodder production technique. The barrier to awareness and adoption could be attributed to the low level of education among the farmers. However, in other published studies, the cost of setting up hydroponics systems was a major barrier (Singh, 2012). Croft *et al.* (2017) also propose the reason for less adoption in developing countries to be subject to the negative perception of the profitability of the hydroponic system and lack of critical evaluation on its potentials. But the author encourages farmers to apply efforts on high-value nutritive crops in areas where soil-based production is not an option. Also, worse climatic factors (namely high hot air and room temperature) and the poor quality of supply water due to high hardiness and salinity (mostly due to sodium chloride) characterize some of the main agronomic constraints for the diffusion of hydroponic systems for the greenhouse (Tognoni and Pardossi 1998).

Perceptions of farmers on hydroponic technology

After a short description of the expression of hydroponic fodder production, farmers expressed an interest in the knowledge and skills at different phases of the process during the production. However, many farmers suspected the nutritive value of the hydroponic fodder, mainly because of scandals concerning the use of inorganic fertilizers on the production of fodder and their respective cost. The same concerns were found by Franzel *et al.* (2003).

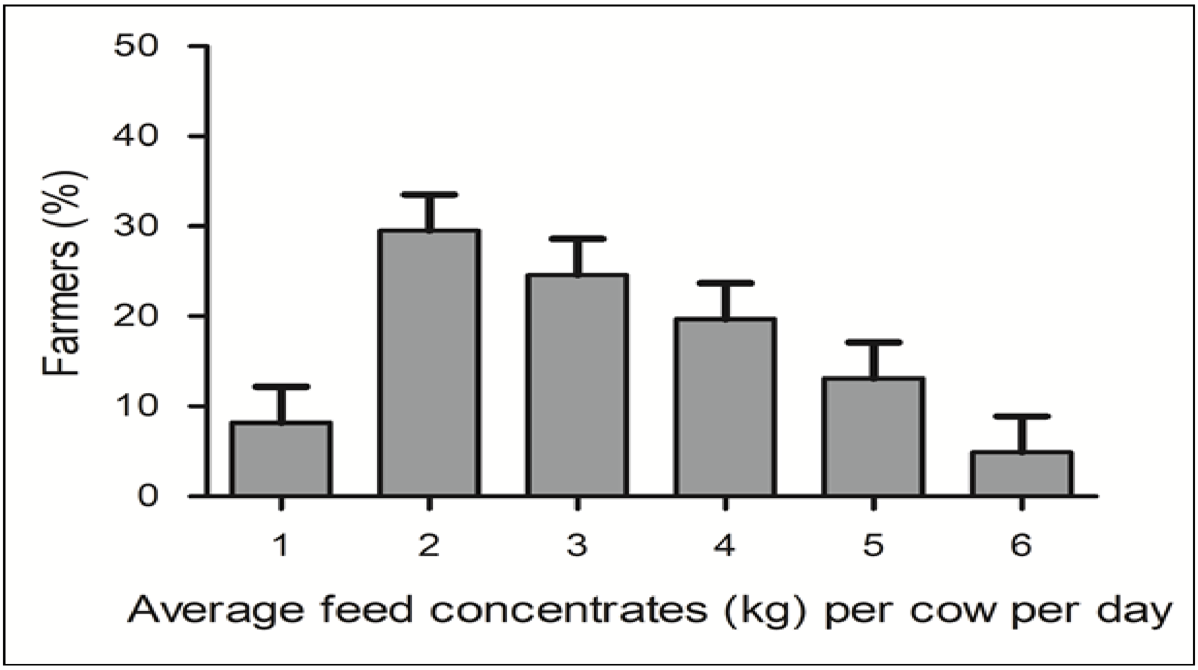

Fig. 5. Average feed concentrate (kg) per cow per day, excluding the minerals and vitamins.

Besides, the farmers expressed concerns about the ability of organic nutrients to produce the high-value hydroponic fodder and the possibility of producing it on a large scale. The use of organic fertilizer in producing high-value hydroponic sprouts on a large scale especially in arid and semi-arid areas has been recommended positively (Tranel, 2013). Moreover, farmers expressed concern about the availability of fodder quality seeds and respective seed costs.

This has been stated to contribute about 90% of the total cost of production for green fodder such as maize fodder (Naik *et al.,* 2015). The concern about the availability and cost of purchasing the seeds may be addressed by investigating the potentials of their relatively available local seeds. Farmers indicated the concerns on the need for a permanent structure such as a greenhouse. The same findings were reported in Fahey (2012) and Tranel, (2013) especially in urban areas. Rico, 2020 suggests small-scale farmer's adoption on hydroponic fodder to start with a well-planned small-scale system that is including the reservoir of water to supply the solution of nutrients to the plants, and a simple platform capable of holding the plants on top of the nutrient solution particularly in areas with or little electricity. Moreover, innovative ideas should be applied to come up with inexpensive hydroponic systems especially in areas where there no enough space for spanning the greenhouses.

Conclusion

Zero-grazing was the most dominant grazing technique employed by the farmers while field grazing was unpopular. Most of the farmers were unfamiliar with HFT and its potential for improving dairy productivity and reducing overreliance to expensive concentrate feeds. The farmers indicated the concerns about hydroponically produced fodders, particularly in issues related to nutritive values, toxicity, and technological costs. We recommend further research to focus on the observed doubts and prioritize the potential of growing the local seeds hydroponically while including options for reducing the cost associated with the hydroponic fodder production inputs and infrastructure.

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Declaration of competing for interest

The manuscript has no competing interests.

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