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ENHANCING GROWTH AND MILK PRODUCTION OF DAIRY BUFFALOES THROUGH HOME-GROWN FORAGES AND COMPLETE NUTRIENT DIET

Daniel L. AQUINO[1], Eric P. PALACPAC[1], Armie M. MOLINA[1], Christian C. LACANILAO[1], Nomer P. GARCIA[1], Arnel N. DEL BARRIO[2], Tsutomu FUJIHARA[1]

[1]*Department of Agriculture-Philippine Carabao Center, Philippines*

[2]*University of the Philippines Los Baños-Dairy Training and Research Institute, Philippines*

Email: ericclap@gmail.com

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ABSTRACT: This study aimed to boost the growth and milk production of dairy buffaloes while increasing farmers' income in Nueva Ecija, Philippines. The approach involved utilizing home-grown forages (HGF), such as napier grass and various legumes (*Leucaena, Rensonii, and Indigofera*), along with a complete nutrient diet (CND). For growing buffaloes, the CND consisted of 23 kg chopped napier grasses, 3 kg legumes, and 1 kg grower concentrates. For lactating buffaloes, the CND comprised 45 kg napier grass, 5 kg legumes, and 2 kg dairy concentrates. Sixty farmers, collectively raising 348 buffaloes, were trained in HGF production and CND preparation. In a 120-day feeding trial for growing buffaloes, a subset of 20 farmers participated, with 10 feeding their buffaloes CND and the other 10 serving as controls. The control group employed traditional feeding practices, involving tethered grazing on native pasture supplemented by cut-and-carry feeding of mixed native grasses. Implementing CND for growing buffaloes resulted in an average daily gain (ADG) of 0.46 kg or an improvement of 53.33% compared to the 0.30 kg ADG observed with traditional feeding. Moreover, CND implementation reduced feed costs, leading to a 98.54% increase in income per growing animal. In a separate feeding trial for lactating buffaloes, another subset of 20 farmers participated, with 10 feeding CND and the remaining 10 serving as controls (traditional feeding). Feeding CND to lactating buffaloes increased daily milk yield from 4.6 kg to 6.0 kg per animal, reflecting a 30.43% improvement compared to those fed with the control diet. This translated to a 41.31% increase in farmers' income over a 180-day lactation period. The findings underline the effectiveness of HGF production and CND feeding in improving the performance of dairy buffaloes and increasing the financial well-being of farmers in Nueva Ecija, marking a significant advancement in sustainable dairy farming practices.

Keywords: Dairy buffaloes; Diet; Home-grown forages; Lactating period; Legumes.

INTRODUCTION

The demand for milk and milk products in the Philippines has steadily increased over the years. Local milk production only fulfills one percent of the total domestic requirements, necessitating substantial imports of dairy products (Hernandez et al., 2022). In 2020, the country imported a total volume of dairy products, equivalent to 2.936 million metric tons of liquid milk (LME) valued at US$1.08 billion (NDA, 2021). Projections indicate a significant rise in per capita consumption of meat, eggs, and milk products for the period 2015-2024, particularly in developing countries in Asia, including the Philippines (OECD/FAO, 2015). The increase in consumption is attributed to expected growth in per capita income in the region. Given the local demand for milk and milk products, government importation has become an inevitable strategy to meet the demand, underscoring the ongoing need to boost local milk production.

The government's farm mechanization program has partially displaced carabaos, the traditional source of draft power for crop farmers. However, through the efforts of the Department of Agriculture-Philippine Carabao Center (DA-PCC) and key stakeholders, carabaos have evolved into multipurpose animals, contributing significantly to protein-rich foods such as milk and meat.

Buffalo as a dairy animal

Dairy buffalo farming is gaining popularity in the Philippines (Tsuji, 2021). The Carabao Development Program (CDP), led by the DA-PCC, aims to enhance milk production from water buffaloes while simultaneously increasing the income and nutrition of smallholder farmers. The introduction of riverine buffaloes from Bulgaria, Brazil, and Italy, along with imported frozen semen from purebred dairy buffalo, aimed to jumpstart buffalo dairying and expedite the transformation of swamp buffalo (Philippine native carabao) into milk and meat producers (Cruz, 2012). Island-born and domestically reared dairy buffaloes can produce an average milk yield of 1,384 kg in a 287-day lactation, and in some cases, as high as 3,364.50 kg in a 300-day lactation (Aquino et al., 2017). With reported milk production figures and farm gate milk

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prices at PHP50/kg, dairy farmers can easily earn PHP168,225 per year, excluding the value of calf production (PCC, 2019). Of the country's 2.873 million carabaos in 2018, only 18,946 (0.659%) are considered potential dairy animals (PSA, 2020). In 2015, dairy carabaos contributed 7.12 metric tons of milk, representing 34.93% of the total national milk production of 20.38 metric tons (PSA, 2016). Records indicate that buffalo milk production consistently increased by 3%-6% annually, making it a significant contributor to the national milk supply.

Buffalo as a meat animal

Buffaloes globally contribute to over three million metric tons of buffalo meat products (Naveena and Kiran, 2014). The carabao's potential as a meat animal creates opportunities in the local wet market, particularly in processed meat products such as corned beef, hot dogs, and sausages. A study by Lapitan et al. (2007) showed that buffalo meat, known locally as "carabeef," from young and properly fed carabaos, is comparable to beef from cattle in terms of tenderness. Carabeef is recognized and favored by consumers as a healthy meat option due to its relatively low fat and cholesterol content, with a high proportion of lean meat (Kandeepan et al., 2009). Improving meat production from carabaos by developing practical rations to enhance average daily gain (ADG) and fattened weight is essential. As a meat animal, the carabao produced 144.680 metric tons of carabeef valued at PHP113.270 million in 2016 (PSA, 2016). This annual carabeef production from slaughtered buffaloes supports 78% of the country's total carabeef requirements.

Feeding management practices for buffaloes

Feeding buffaloes for both meat and milk production demands well-balanced rations to meet their nutritional needs for optimal growth and milk production. Meat and milk synthesis are among the most nutrient-demanding physiological and metabolic processes, and an imbalance in nutrients can lead to weight loss and health issues. A well-balanced ratio of protein, energy, vitamins, and minerals in a palatable feed is crucial for increasing milk production, live weight, as well as improving the health and fertility of the animals (Thomas, 2008).

Buffalo feeding is also influenced by seasonality of forage supply and cropping patterns. In regions like Nueva Ecija, forage is scarce during the dry season (December to May) and the rainy months (July to August) when all paddies are planted with rice (Aquino et al., 2020), resulting in poor growth, body condition, and milk production for buffaloes. To mitigate this, dairy farmers often use crop by-products like rice straw as fodder, but these have low nutritive value (Rusdy, 2022), leading to suboptimal animal performance and reduced income.

For dairy farmers, prioritizing forage quality is essential in optimizing the health and productivity of their buffalo herds. Understanding that the nutritional quality of forages significantly impacts animal productivity, farmers must focus on factors such as energy concentration and crude protein levels to meet the dietary requirements of dairy buffaloes (Collins et al., 2017). Forages with higher digestibility provide more energy per unit of dry matter consumed, thereby enhancing animal performance. Additionally, variations in forage composition, including fiber levels and susceptibility to microbial digestion, further underscore the importance of selecting high-quality forages. By prioritizing forage quality, farmers can optimize feed efficiency and promote the health and productivity of their buffalo herds, ensuring sustainable and profitable meat and milk production.

Home-grown forages and complete nutrient diet

Addressing the nutritional challenges faced by buffaloes in meat and milk production underscores the crucial role of home-grown forages (HGF) in ensuring a sustainable and productive feeding strategy. This importance aligns with the broader recognition of HGF's pivotal role in enhancing sustainability and productivity in ruminant production and dairying, as evidenced by insightful studies. For instance, Zucali et al. (2018) conducted a comprehensive environmental impact assessment of different cropping systems for home-grown feed in Northern Italy, emphasizing the crucial link between farmer choices in forage selection and the environmental footprint of milk production. Meanwhile, Chapman et al. (2014) explored the potential for increased HGF consumption and profit in non-irrigated dairy systems in southern Australia, highlighting the intricate balance between perennial ryegrass-dominant pastures and alternative forage options to achieve optimal productivity. Fariña and Chilibroste (2019) extended this perspective to Uruguay, analyzing farm systems to identify opportunities and challenges for the growth of pasture-based dairy production, underscoring the importance of overcoming economic, social, and environmental constraints. Additionally, Campbell (2019) delved into the utilization of HGF legumes, revealing their potential as protein sources for high-yielding dairy cows, particularly with the strategic use of tannins to enhance protein availability. Tharmaraj et al. (2014) further emphasized the practical implementation of complementary forages to achieve a substantial increase in forage harvested per hectare, showcasing the tangible benefits of diversified forage systems. Collectively, these studies underscore the significance of HGF in not only improving production efficiency and profitability but also in addressing environmental concerns and promoting sustainable practices in ruminant production and dairying.

Elevating sustainability and profitability, HGF lay the foundation for a comprehensive approach to modern livestock nutrition. The concept of providing ruminants or dairy animals with a complete and balanced diet is a critical aspect of contemporary livestock management, aiming to optimize production efficiency and overall health. This approach involves formulating complete nutrient diets (CND), complete feeds, or total mixed rations (TMR) that encompass all necessary dietary components in appropriate proportions. Beigh et al. (2017) highlighted the importance of the complete feed system, emphasizing its role in preventing feed separation and stabilizing ruminal fermentation, ultimately leading to improved nutrient utilization. Delving into the comparative performance of pelleted napier grass-based TMR with *Indigofera*, Limao and Pomares (2022) showcased the potential of such complete ration mixes in terms of feed intake, weight gain, and rumen degradability. Additionally, Karunanayaka et al. (2022) underscored the significance of TMR in dairy cows, emphasizing its substantial effects on body weight, feed efficiency, milk yield, and reproductive performance. Collectively, these studies underscored the pivotal role of complete diets or feeds in ensuring a well-rounded and nutritionally balanced approach to ruminant and dairy animal nutrition, ultimately contributing to enhanced productivity and overall well-being.

Given the above context, we hypothesize that the integration of a sustainable supply of HGF with a well-formulated CND will significantly enhance the growth and milk production of dairy buffaloes in the province of Nueva Ecija. We posit that the strategic combination of HGF and CND will result in improved animal performance, optimal body weight, enhanced feed efficiency, increased milk yield, and improved cost-benefit outcomes. This hypothesis establishes the groundwork for a novel and comprehensive approach to ruminant and dairy animal nutrition in the Philippines, focusing on the synergy between locally sourced forages and carefully designed CND to achieve holistic benefits for the animals and increased economic viability for the farmers.

The current study aims to enhance the growth and milk production of dairy buffaloes in the province of Nueva Ecija in the Philippines by establishing a sustainable supply of HGF and developing a CND. Specifically, the objectives include establishing village-scale production of home-grown grasses and legumes, utilizing harvested HGF to develop and test a CND, and evaluating animal performance and the benefits of feeding the diet to growing and lactating buffaloes using a cost-benefit analysis.

MATERIALS AND METHODS

Preliminary survey

A preliminary survey was conducted to assess the current feeding management practices of dairy farmers in Nueva Ecija. The survey involved personal interviews with 168 dairy farmer-informants from various locations, including rain-fed and irrigated areas, as well as different herd sizes (less than 5 head, 6-10 head, 11-20 head, and more than 20 head).

Capability building

Prior to the technology demonstrations, partner farmers from Nueva Ecija participated in a training program titled "Science-Based Production of Grasses and Legumes for Year-Round Supply of Fodders". This training equipped the farmers with practical skills related to land preparation, preparation of planting materials, actual planting, and cultural management practices for their forage gardens. Additionally, the research project established a legume nursery and provided farmers with thousands of legume-potted seedlings. Napier grass cuttings and legume seedlings were distributed to the farmers based on a first-come-first-served basis upon completion of land preparation. Essential tools and farm equipment, including hand tractors and water pumps, were provided to support their farm demonstrations.

Activity 1: production of home-grown grasses and legumes

This activity encompassed two major components: the production of home-grown grass and legume plantations for seed and the production of HGF for use as a source of fodder.

Establishment of grass-legume plantation for seed production

A 10-hectare forage area at the DA-PCC site in Carranglan, Nueva Ecija, was designated for the establishment of grass and legume plantations for seed production. The grass-legume plantation included *Stylosanthes, Indigofera, Rensonii, Leucaena, Gliricidia,* and *Cajanus*, with each species occupying one hectare. Additionally, four hectares were allocated for improved grasses: Napier Pakchong (*Pennisetum purpureum* cv. Pakchong 1), Mulato (*Urochloa brizantha*), Mombasa (*Panicum maximum*), and Ruzi (*Brachiaria ruziziensis*).

Production of HGF

Sixty dairy farmers from 20 primary dairy cooperatives in Nueva Ecija participated in the on-farm production of HGF. These farmers were divided into two groups: 30 from irrigated areas (Group 1) and 30 from rain-fed areas (Group 2). Farmers in both groups owned one to five animals each (Table 1). The selection of partner farmers was based on their interest in participating in the research, their willingness to utilize their farm resources, and their commitment to record-keeping and data sharing.

Farmers were provided with four types of legume seedlings: *Indigofera, Rensonii, Leucaena,* and *Gliricidia*. However, Super Napier or Pakchong grass and two legume varieties, *Indigofera* and *Rensonii*, were the preferred choices for most of the farmers. The area of forage gardens was determined based on the number of animals raised and their annual fodder requirements. For example, an animal weighing 500 kg would require a daily feed equivalent to 2.5% of its body weight (on a dry matter basis), translating to a 550 m^2 forage garden per animal per year on a cut-and-carry system basis.

Table 1 - Layout of the production of home-grown forages

Forage Area	Animal holding (head)	Types of Forage	No. of Farmers
Group 1: Rain-fed	1-5	Grass and Legume	30
Group 2: Irrigated	1-5	Grass and Legume	30
Total			60

Grass includes mainly napier grass; Legumes include *Leucaena, Rensonii, and Indigofera*

Land preparation and planting method

Farmers conducted mechanized land preparation of their forage areas, including disc ploughing and harrowing to ensure proper soil preparation. Furrows were established for planting napier grass, while legumes were planted without furrows. Planting materials were distributed on a first-come-first-served basis, and planting was done in a systematic manner, alternating between napier grass and legumes.

Cultural management practices

Farmers implemented common management practices, including fertilizer application, irrigation, and off-baring of the plants. Fertilizer application was conducted two to three weeks after planting and one week after each harvest using a mixture of urea and complete fertilizer. Irrigation was performed as needed, with a focus on maintaining soil moisture during dry periods. Off-baring of napier grass was practiced twice a year to facilitate regrowth. Farmers monitored the growth and development of the plants closely.

Harvesting of forage and estimation of yield and quality

Forages were harvested manually by the partner farmers when the grass and legume plants reached maturity, generally around six months from planting. Harvesting intervals were set at 45-55 days for napier grass and 60 days for legumes. The fresh and dry matter yields per hectare were estimated using a quadrat method, and samples of grasses and legumes were collected and analyzed for nutrient composition at the DA-PCC Nutrition laboratory. The dry matter content was used to calculate the dry matter yield of napier grass and legumes per hectare.

Activity 2: development and testing of CND utilizing HGF for growing buffaloes

Development of CND for growing buffaloes

The development of the CND for growing buffaloes was based on feed reference standards published by Kearl (1982). The CND was designed to provide the necessary nutrients to support an average daily gain (ADG) of 500 grams in growing animals. It included a mixture of 23 kg chopped napier grasses and 3 kg legumes harvested from the HGF plus 1 kg grower concentrates and mineral mix.

Nutritional evaluation of CND

Twenty dairy farmers, each raising one growing buffalo heifer, participated in testing the CND. The heifers were selected based on similar breed (Bulgarian Murrah), initial weights, ages (around 1-2 years old), and body condition scores (2.5-3.0). Ten of the farmers fed their heifers with CND for 120 days. The other ten farmers served as the control group and followed traditional feeding practices, i.e., tethered grazing on native pasture plus 25 kg mixed native grasses offered through cut-and-carry feeding system. Animals in the control group also received l kg supplementary concentrates and mineral mix to balance their rations.

Development of CND for lactating buffaloes

The development of the CND for lactating buffaloes also followed feed reference standards by Kearl (1982). The CND was designed to provide the necessary nutrients to support a target milk production of seven kilograms of milk per day per cow. The composition included 45 kg of napier grass, 5 kg legumes, and 2 kg dairy concentrates, formulated to meet the nutrient requirements for daily milk production.

Actual CND feeding

Twenty dairy farmers participated in the feeding of CND using their own dairy animals, which were of the same breed (Bulgarian Murrah) and were in their third parity. These lactating buffaloes had an average initial daily milk yield of 4.43 kilograms. Ten farmers fed their lactating buffaloes with the developed CND, while the other ten followed traditional feeding practices, including tethered grazing and the cut-and-carry system. The parameters collected included daily feed intake, milk production, and changes in body weights of the animals. Simple cost-benefit analyses were also conducted, considering feed cost to produce a kilogram of milk and income from milk over feed cost.

RESULTS AND DISCUSSION

Preliminary survey on feeding practices

The preliminary survey revealed important insights into the feeding practices of dairy farmers in Nueva Ecija. Approximately 40% of the total farmer-informants reported having forage gardens ranging from 200-400 m^2, primarily planted with napier grass to serve as a source of fodder for their buffaloes. An alarming 92% of these farmers faced forage or feed scarcity, with 74.9% experiencing shortages from January to June and 17.2% from July to December. This scarcity partly explains why 76% of these farmers continued to follow traditional feeding practices, which involved tethering their animals in communal fields and providing minimal concentrate supplementation, with a focus on utilizing farm by-products.

Production of home-grown grasses and legumes

In this activity, the research project team played a crucial role in establishing a forage nursery and providing thousands of potted legume seedlings, including *Leucaena leucocephala, Indigofera suffruticosa, Desmodium rensonii,* and *Gliricidia sepium*. After receiving training on “Science and Technology-based Production of Grasses and Legumes for Year-round Fodder Supply for Dairy Buffaloes” and a “Refresher Course on Forage Production, Conservation, and Utilization”, 175 farmers embarked on land preparation. The distribution of planting materials followed a first-come-first-served basis, considering the readiness of the planting area. Furthermore, the research project provided crucial farm equipment such as hand tractors and water pumps to support the farmers’ efforts. A total of 60 dairy farmers with 348 buffaloes participated in this initiative. They received 129,620 legume seedlings and 613,000 Napier grass cuttings, enabling them to establish a collective 26.1 hectares of HGF. The project also supplied small farm implements, including sprinklers, water pumps, knapsack sprayers, and fertilizers, as inputs for HGF production.

Monitored growth rate of plants

Comparing irrigated and rain-fed areas, the growth and regrowth rates of napier grass, *Rensonii*, and *Indigofera* indicated faster development in the irrigated areas at both 60-day and 90-day harvest intervals, with plant heights of 183 cm, 174 cm, and 160 cm, respectively. In contrast, slower growth was observed in the rain-fed areas, particularly for *Leucaena*, which reached only 44 cm in height at a 60-day cutting interval and 94 cm at a 90-day cutting interval (Table 2). The current research findings, illustrating faster growth rates of forage species in irrigated areas compared to rain-fed areas, align with existing literature indicating the significant influence of water availability on forage growth (Kumar et al., 2022; Ren et al., 2021; Baath et al., 2020; Mendoza-Grimón et al., 2021), emphasizing the importance of water management in optimizing forage and legume production for livestock feed.

Herbage yield of the forages

Indigofera demonstrated higher dry matter (DM) yields compared to *Rensonii* and *Leucaena*, regardless of whether they were grown in rain-fed or irrigated conditions (Table 3). In the irrigated areas, *Indigofera* stood out with the highest DM yield of 10,120.68 kg/ha at a 90-day cutting interval, while *Leucaena* had the lowest DM yield of 3,337.51 kg/ha. This data highlighted the preference of dairy farmers for *Indigofera* in HGF production, given its ability to thrive in both rain-fed and irrigated conditions while providing higher protein content compared to *Rensonii* and *Leucaena*.

Overall, DM yields of napier grass and the three legume species were notably higher in the irrigated areas compared to those in the rain-fed areas. Napier grass DM yields at a 90-day cutting frequency in both areas indicated an average increase of 13.44% compared to 60-day cutting intervals. While *Leucaena* showed no significant difference in DM yields based on planting sites and cutting frequencies, *Rensonii* displayed significant variations in DM yields between 60-day and 90-day cutting intervals. Similarly, *Indigofera* exhibited significant differences in DM yields between 90-day and 60-day cutting intervals. These results resonate with Geren et al. (2020) and Bantihun et al. (2022), which suggested that longer cutting intervals promote greater biomass accumulation, potentially resulting in higher forage productivity. Although direct comparisons are lacking, the overall trend supports the inference that forage grasses and legumes may yield more dry matter with a 90-day cutting interval, highlighting the importance of cutting frequency in maximizing productivity (Dinsa and Yalew, 2022).

Nutrient composition

The nutrient composition analysis of napier grass and legume species revealed the quality of available fodders for developing the CND (Table 4). *Leucaena* demonstrated the highest crude protein (CP) content, reaching 21.57% at a 45-day cutting frequency, followed by *Indigofera* (21.31%) and *Rensonii* (18.26%). *Indigofera* consistently outperformed *Leucaena* and *Rensonii* in terms of CP content at various cutting intervals. This supports the earlier observation that *Indigofera* exhibited higher CP content than some other legume species (Syamsi et al., 2022). The data also confirmed that farmers preferred *Indigofera* due to its higher DM yields and superior protein content, which indicated its capacity to support more animals per hectare of forage plantation.

Table 2 - Average plant heights of home-grown forages

Site/Location	Cutting Interval (days)	Napier grass (cm)	*Indigofera* (cm)	*Rensonii* (cm)	*Leucaena* (cm)
Group 1: Rain-fed	60	139	83	85	44
	90	150	152	147	74
Group 2: Irrigated	60	165	90	93	50
	90	183	160	174	94

Table 3 - Dry matter yield/hectare of home-grown forages planted by the farmers

Site/Location	Cutting Interval (days)	Napier grass (kg)	*Indigofera* (kg)	*Rensonii* (kg)	*Leucaena* (kg)
Group 1: Rain-fed	60	12,700.00	3,958.95	2,610.29	2,078.90
	90	14,300.00	8,069.41	6,727.58	3,185.22
Group 2: Irrigated	60	13,300.00	5,254.70	6,044.99	2,234.00
	90	15,200.00	10,120.68	8,437.45	3,337.51

Table 4 - Nutrient composition of home-grown forages

Days	Grass/ Legumes	Herbage Yield/Plant (g)	DM (%)	Ash (%)	OM (%)	Crude Fat (%)	Crude Protein (%)	Fiber (%)	ADF (%)	NDF (%)
45	Napier	1,100.00	24.79	13.81	86.19	8.31	11.9	25.95	-	52.72
	Indigofera	561.49	24.63	10.36	89.64	2.51	21.31	18.66	25.04	35.82
	Rensonii	260.48	23.36	8.15	91.85	1.27	18.26	26.42	23	35.99
	Leucaena	188.89	32.49	8.05	91.95	2.55	21.57	18.29	18.78	35.57
60	Napier	1,270.00	25.76	14.13	85.6	8.15	10.15	32.66	-	58.08
	Indigofera	1,067.00	25.84	10.22	89.78	2.4	23.31	19.12	21.11	31.61
	Rensonii	946.33	24.12	8.43	91.57	1.12	18.67	27.68	21.07	34.98
	Leucaena	568.75	22.04	7.57	92.44	2.6	22.96	19.68	18.02	32.92
90	Napier	1,730.00	27.5	14.41	85.59	7.69	9.95	32.66	-	59.67
	Indigofera	3,087.50	23.14	10.17	89.83	3.75	23.24	15.26	23.2	31.92
	Rensonii	1,878.60	23.4	8.17	91.83	2.84	20.01	25.28	23.13	36.19
	Leucaena	803.33	23.79	7.97	92.03	4.34	21.13	20.24	18.32	35.62

DM=Dry Matter; OM=Organic Matter; ADF=Acid Detergent Fiber; NDF=Neutral Detergent Fiber

Development and testing of CND utilizing HGF for growing buffaloes

Effect of CND on growing buffaloes

The technology demonstration involving the feeding of CND to growing buffaloes spanned 120 days. The 10 farmers who adopted CND observed an average final body weight of 296.56 kg, representing an average daily gain (ADG) of 0.46 kg. In contrast, buffaloes fed with the control diet reached a final weight of 270.44 kg, with an ADG of only 0.30 kg (Table 5). Initially, there was no significant difference in the initial weights of buffaloes between the two feeding groups. However, by the end of the feeding period, buffaloes on the CND showed a trend towards higher final weights compared to those on the standard ration (Figure 1), although the difference was not statistically significant. Notably, buffaloes fed with the CND exhibited a significantly higher ADG and total weight gain compared to those on the standard ration, with p-values of 0.002, indicating highly significant differences. This suggests that the CND contributed to improved growth performance, resulting in faster weight gain and greater overall growth in the buffaloes over the feeding period.

Effects of CND on feed intake of growing buffaloes

Buffaloes fed with CND consumed 27 kg/hd/day on an as-fed basis, consisting of 23 kg of napier grass, 3 kg of legume, and 1 kg of concentrates. In comparison, animals fed with the control diet, which included 25 kg of napier grass and 1 kg of concentrate, consumed 26 kg/day. Buffaloes given CND achieved a daily dry matter intake (DMI) of 7.42 kg, equivalent to 2.6% of their body weight. This DMI was 1.16 kg higher than buffaloes on the control diet, which had a DMI of 7.17 kg/day, representing 2.52% of their body weight. These observed DMIs aligned with the published data by Kearl (1982), which reported DMI ranges of 2.2% to 2.9% of body weight and ADGs between 0.25 kg and 0.50 kg for growing buffaloes. Previous studies on the effects of forage legumes, such as those included in the CND, corroborate our findings by demonstrating the positive impact of these legumes on DMI and growth rate in ruminants (Durango et al., 2021; Maña et al., 2023). For instance, Durango et al. (2021) showed that forage legumes *like Leucaena leucocephala* can improve DMI and nitrogen retention in Zebu steers, leading to enhanced growth performance under tropical conditions. Furthermore, the study by Maña et al. (2023) demonstrated that the inclusion of legumes like *Indigofera tinctoria* in mixed swards can increase feed intake and improve growth performance in goats. These findings collectively support the notion that incorporating forage legumes into the diets of ruminants can positively influence DMI and growth rates, ultimately enhancing overall productivity.

Simple cost-benefit analysis of CND feeding in growing buffaloes

Farmers who adopted CND feeding for their growing buffaloes incurred a higher daily feed cost (FC) of PHP58 compared to PHP45 for the control diet (Table 6). However, when the FC per kilogram of weight gain was calculated, the CND-fed buffaloes exhibited significantly lower costs of PHP126.27 compared to PHP150.00 for those on the control diet. This reduction of PHP24.14 in FC per kilogram of weight gain in buffaloes fed with CND was attributed to their higher ADG, indicating that the additional nutrients provided by CND were efficiently utilized by the animals for lean meat production. Based on the total weight gain, the income over the cost of feeding CND to buffaloes reached PHP5,718.00, representing a 98.54% increase compared to the PHP2,880.00 for buffaloes fed with the control diet.

Development and evaluating of CND for lactating buffaloes

Feed intake of CND-fed lactating buffaloes

The introduction of CND did not significantly affect the daily feed intake of lactating dairy buffaloes. Buffaloes fed with the control diet consumed slightly more on an as-fed basis, with 47.00 kg compared to 45.31 kg per day for those on CND (Table 7).

Effect of CND feeding on Milk production

The adoption and feeding of CND resulted in a significant improvement in daily milk production (Figure 2). Dairy buffaloes given CND produced an average daily milk yield of 6.0 kg, while those following their usual feeding practices (control diet) yielded 4.6 kg/head/day. This translated to an increase of 1.4 kg in daily milk yield due to CND feeding, resulting in a higher total milk yield over a 180-day lactation period. These findings are consistent with previous literature, suggesting that incorporating legumes into the diet, as seen in the CND, enhances milk production in dairy animals (Mutimura et al., 2018; Gannuscio et al., 2022).

Simple cost-benefit analysis of CND feeding in lactating buffaloes

The daily cost of feeding CND was PHP101, which was PHP4.74 higher than the PHP96.25/day for the control diet. However, when expressed in terms of FC to produce a kilogram of milk, the trend reversed. Farmers spent only PHP16.83 per day to produce a kilogram of milk when using CND, compared to PHP20.92 for those on the control diet. Feeding CND to buffaloes generated a higher income of PHP57,420, compared to only PHP40,635 with the control diet during 180 milking days, representing a 41.31% increase in farmers' income.

Table 5 - Change in body weight of growing buffaloes fed with standard ration and complete nutrient diet

Parameters	Standard ration (control)		Complete nutrient diet		P-value
	Mean/SE (N=10)	SD	Mean/SE (N=10)	SD	
Initial weight, kg	234.44±11.64	34.92	241.44±12.72	38.16	0.909
Final weight, kg	270.44±12.48	37.44	296.56±17.77	53.32	0.083
ADG, kg	0.30±0.05	0.16	0.46±0.06	0.2	0.002**
Total weight gain, kg	36.00±6.31	18.93	55.12±07.88	23.63	0.002**

** highly significant (P<0.01); ADG = Average Daily Gain

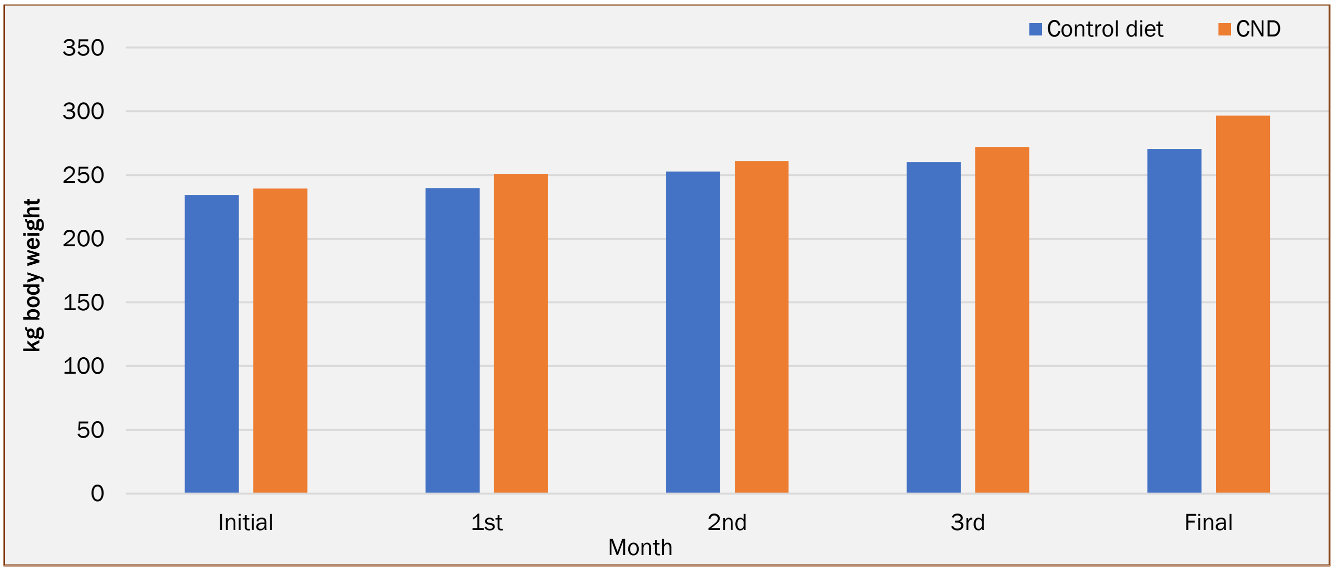

Figure 1 - Monthly body weight of buffaloes fed with complete nutrient diet (CND) and control diet

Table 6 - Simple cost-benefit analysis of feeding complete nutrient diet (CND) to growing buffaloes

Parameters	Standard ration (control)	Complete nutrient diet
No. of animals	10	10
Feeding period, days	120	120
Initial weight, kg	234.44	241.44
Final weight, kg	270.44	296.56
Total weight gain, kg (a)	36[a]	55.12[b]
Average daily gain, kg	0.30[a]	0.46[b]
Income from total weight gain, PHP*(b)	8,280	12,678
Feed intake, kg	26	27
Grass**	25	23
Legume***	–	3
Concentrate****	1	1
Feed cost/day, PHP	45	58
Feed cost/120 d, PHP (c)	5,400	6,960
Feed cost/kg BW, PHP (c/a)	150.00	126.27
Income-Feed Cost, PHP (b-c)	2,880	5,718
% Income Improvement		98.54

*PHP230/kg lean x total weight gain (kg); ** PHP1.00/kg; *** PHP 5/kg; **** PHP 20/kg; (PHP: Philippine peso)

Table 7 - Simple cost-benefit analysis of feeding complete nutrient diet to dairy buffaloes

Parameters	Standard ration (control)	Complete nutrient diet
No. of animals	10	10
Milk yield, kg/d	4.6a	6.0b
Total Milk Yield, kg **(a)**	828	1,080
Days in milk	180	180
Income from milk sales, PHP* (b)	57,960	75,600
Feed intake, kg/d	47	45.31
Feed cost/day, PHP	96.25	101
Feed cost/180 d, PHP (c)	17,325	18,180
Feed cost/kg milk, PHP (c/a)	20.92	16.83
Income-Feed Cost, PHP (b-c)	40,635	57,420
% Income Improvement	—	41.31

*PHP 70/kg

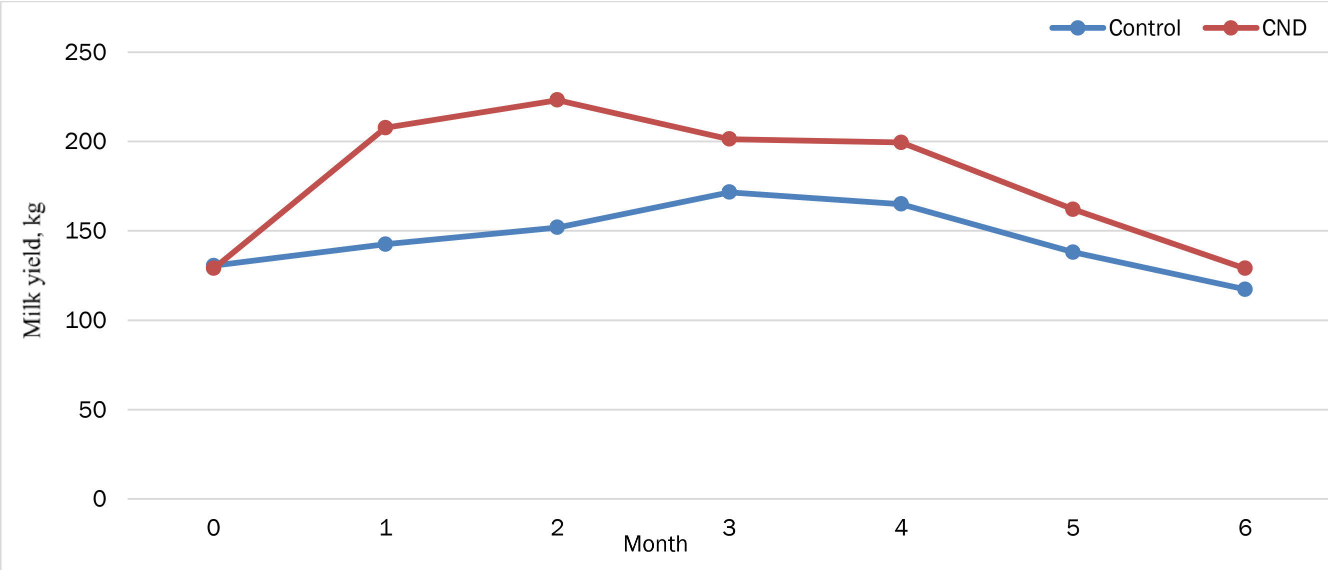

Figure 2 - Milk production of dairy buffaloes fed with complete nutrient diet (CND) and control diet

CONCLUSION

This study successfully addressed its objectives of enhancing the growth and milk production of dairy buffaloes in the province of Nueva Ecija, Philippines, through the strategic integration of home-grown forages (HGF) and a complete nutrient diet (CND). The findings align with the formulated hypothesis, as the synergistic combination of HGF and CND resulted in notable improvements in animal performance, including increased average daily gain in growing buffaloes and enhanced daily milk yield in lactating buffaloes. The results further demonstrated the economic viability of the approach, with a significant increase in income for farmers who adopted CND feeding practices. Despite the lack of statistical significance in some growth parameters, the observed positive trends in body weight, feed efficiency, and milk production support the overall success of the study. This research contributes to the advancement of sustainable dairy farming practices in the Philippines, emphasizing the importance of locally sourced forages and well-formulated CNDs in optimizing ruminant nutrition and promoting economic well-being among smallholder farmers.

DECLARATIONS

Corresponding author

Correspondence and requests for materials should be addressed to Eric P. PALACPAC; E-mail: ericclap@gmail.com; ORCID: https://orcid.org/0000-0003-3674-2113

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Authors' contribution

The first author spearheaded the design and execution of the experiments, conducted results analysis, and contributed to the writing. The second author was involved in writing, results analysis, and refining the manuscript's structure. The third and fourth authors participated in data collection and lab analysis. The fifth author played a key role in establishing HGF production sites and coordinating with participating farmers. Lastly, the sixth and seventh authors contributed to the results analysis.

Data availability

The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

Ethical considerations

The feeding trials conducted as part of this research were carried out in strict accordance with the ethical guidelines and protocols established by the Research Ethics Committee of the funding agency. The welfare and humane treatment of all animals involved in the trials were of paramount concern, and every effort was made to ensure their well-being throughout the experimental process. Additionally, the collection and handling of data from participating farmers adhered rigorously to the principles outlined in the Data Privacy Act of the Philippines. The confidentiality and privacy of farmer-related information were strictly maintained, and all data were handled with the utmost sensitivity and in compliance with relevant legal and ethical standards. Likewise, this study is reported in accordance with ARRIVE guidelines (https://arriveguidelines.org). All methods were performed in accordance with the relevant guidelines and regulations.

Competing interests

The authors declare no competing interests.

REFERENCES

Aquino DL, Del Barrio AN, Trach NX, Hai NT, Khang DN, Toan NT and Van Hung N (2020). Rice straw-based fodder for ruminants. Sustainable rice straw management. Springer, Cham. pp. 111-129. DOI: https://doi.org/10.1007/978-3-030-32373-8_7

Aquino DL, Rosario MVd, Vergara K and Cruz LC (2017). Augmented Feeding with By-passed Amino Acid and Slow-released Non-protein Nitrogen Supplement on Milk Peak, Lactation Persistency, and Post-partum Reproduction of Brazilian Buffaloes. Available online: https://repository.pertanian.go.id/server/api/core/bitstreams/b253cf21-197f-439f-81c4-6fd29bd69fb9/content.

Baath GS, Rocateli AC, Kakani VG, Singh H, Northup BK, Gowda PH, and Katta JR (2020). Growth and physiological responses of three warm-season legumes to water stress. Scientific Reports, 10(1), 12233. DOI: https://doi.org/10.1038/s41598-020-69209-2

Bantihun A, Asmare B, and Mekuriaw Y (2022). Comparative evaluation of selected grass species for agronomic performance, forage yield, and chemical composition in the highlands of Ethiopia. Advances in Agriculture, 2022. DOI: https://doi.org/10.1155/2022/6974681

Beigh YA, Ganai AM and Ahmad HA (2017). Prospects of complete feed system in ruminant feeding: A review. Veterinary world 10(4): 424. DOI: https://doi.org/10.14202/vetworld.2017.424-437

Campbell C (2019). Improving the utilisation of home grown forage legumes by high yielding dairy cows. Harper Adams University. Available online: https://hau.repository.guildhe.ac.uk/id/eprint/17441

Chapman DF, Hill J, Tharmaraj J, Beca D, Kenny SN and Jacobs JL (2014). Increasing home-grown forage consumption and profit in non-irrigated dairy systems. 1. Rationale, systems design and management. Animal Production Science 54(3): 221-233. DOI: https://doi.org/10.1071/AN12295

Collins M, Newman YC, Nelson C, Barnes R and Moore K (2017). Forage quality. Forages 1: 269-286.

Cruz LC (2012). Transforming Swamp Buffaloes to Producers of Milk and Meat through Crossbreeding and Backrossing. The Journal of Animal and Plant Sciences 22: 157-168. Available online: https://www.thejaps.org.pk/docs/Supplementary/03/008.pdf

Dinsa NG and Yalew KD (2022). The effect of intercropping of lablab (Lablab purpureus L.) and cowpea (Vigna unguiculata L.) at different planting densities on In vitro and In sacco dry matter digestibility of napier grass (Pennisetum purpureum). Agricultural Science Digest-A Research Journal, 42(3), 249-259. DOI: https://doi.org/10.18805/ag.DF-390

Durango SG, Barahona R, Bolívar D, Chirinda N and Arango J. (2021). Feeding strategies to increase nitrogen retention and improve rumen fermentation and rumen microbial population in beef steers fed with tropical forages. Sustainability, 13(18), 10312. DOI: https://doi.org/10.3390/su131810312

Fariña SR and Chilibroste P (2019). Opportunities and challenges for the growth of milk production from pasture: The case of farm systems in Uruguay. Agricultural Systems 176: 102631. DOI: https://doi.org/10.1016/j.agsy.2019.05.001

Gannuscio R, Ponte M, Di Grigoli A, Maniaci G, Di Trana A, Bacchi M, Alabiso M, Bonanno A, and Todaro, M. (2022). Feeding dairy ewes with fresh or dehydrated sulla (*Sulla coronarium* L.) Forage. 1. Effects on feed utilization, milk production, and oxidative status. Animals, 12(18), 2317. DOI: https://doi.org/10.3390/ani12182317

Geren H, Kavut Y, and Hayrullah UNLU (2020). Effect of different cutting intervals on the forage yield and some silage quality characteristics of giant king grass (Pennisetum hybridum) under Mediterranean climatic conditions. Turkish Journal of Field Crops, 25(1), 1-8. DOI: https://doi.org/10.17557/tjfc.737467

Hernandez HE, Mercado TE, Sobremonte EM and Rosete MA (2022). Analyzing the Efficiency of Dairy Production in the Philippines. International Journal of Social and Management Studies 3(1): 87-111. DOI: https://doi.org/10.5555/ijosmas.v3i1.91

Kandeepan G, Biswas S and Rajkumar R (2009). Buffalo as a potential food animal. International Journal of Livestock Production 1(1): 001-005. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=2584704e79da1fb2db02af422a2ae83adb1c35be

Karunanayaka RHWM, Liyanage RTP, Nayananjalie WAD, Kumari MAAP, Somasiri SC, Adikari AMJB and Weerasingha WVVR (2022). Feeding Total Mixed Ration (TMR) on Production and Reproductive Performance of Lactating Dairy Cows: AReview. Agricultural Reviews 43(1): 29-37.DOI: https://doi:10.18805/ag.R-208

Kearl LC (1982). *Nutrient requirements of ruminants in developing countries*: International Feedstuffs Institute. Available online: https://www.cabidigitallibrary.org/doi/full/10.5555/19830744565

Kumar R, Pareek NK, Rathore VS, Nangia V, Kumawat A, Kumar A, Pareek B, and Meena M (2022). Performance of Cluster Bean (Cyamopsis tetragonolaba) under Varying Levels of Irrigation and Nitrogen. Legume Research – An International Journal, 1, 7. DOI: https: 10.18805/LR-4897

Lapitan RM, Del Barrio AN, Katsube O, Ban-Tokuda T, Orden EA, Robles AY, Fujihara T, Cruz LC, Homma H and Kanai Y (2007). Comparison of carcass and meat characteristics of Brahman grade cattle (Bos indicus) and crossbred water buffalo (Bubalus bubalis). Animal Science Journal 78(6): 596-604. DOI: https://doi.org/10.1111/j.1740-0929.2007.00480.x

Limao E and Pomares CC (2022). Comparative Performance of Pelleted Napier Grass (Pennisetum purpureum)-based with Indigofera: A Complete Ration Mix (CRM) fed to Grower Sheep. Asian Journal of Research in Animal and Veterinary Sciences 9(3): 8-14. Available online: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4093430

Maña MAT, Niepes RA, Florida MAC, and Paculba RA (2023). Growth performance of goats (*Capra hircus* L.) on forage legumes mixed with Guinea grass (*Megathyrsus maximus*). DOI: https://doi.org/10.22194/jgias/23.1169

Mendoza-Grimón V, Amorós R, Fernández-Vera JR, Hernádez-Moreno JM, Palacios-Díaz MdP. Effect of Different Water Quality on the Nutritive Value and Chemical Composition of Sorghum bicolor Payenne in Cape Verde. *Agronomy*. 2021; 11(6):1091. DOI: https://doi.org/10.3390/agronomy11061091

Mutimura M, Ebong C, Rao IM, and Nsahlai IV (2018). Effects of supplementation of *Brachiaria brizantha* cv. Piatá and Napier grass with *Desmodium distortum* on feed intake, digesta kinetics and milk production in crossbred dairy cows. Animal Nutrition, 4(2), 222-227. DOI: https://doi.org/10.1016/j.aninu.2018.01.006

Naveena B and Kiran M (2014). Buffalo meat quality, composition, and processing characteristics: Contribution to the global economy and nutritional security. Animal frontiers 4(4): 18-24. DOI: https://doi.org/10.2527/af.2014-0029

NDA (2021). Philippine Dairy Update. National Dairy Authority. Available online:https://nda.da.gov.ph/images/2021/data/OCT/philupdate-lme.pdf

OECD/FAO (2015). OECD-FAO Agricultural Outlook (2015-2024). DOI: http://dx.doi.org/10.1787/agr_outlook-2015-en.

PCC (2019). 2018 PCC Annual Report.: Philippine Carabao Center.

PSA (2016). Dairy Industry Performance Report. Philippine Statistics Authority.

PSA (2020). Special Release: Carabao Situation Report (October-December 2019). Philippine Statistics Authority. Available online: https://psa.gov.ph/content/carabao-situation-report-october-december-2019-0

Ren L, Bennett JA, Coulman B., Liu J, and Biligetu B (2021). Forage yield trend of alfalfa cultivars in the Canadian prairies and its relation to environmental factors and harvest management. Grass and forage science, 76(3), 390-399. DOI: https://doi.org/10.1111/gfs.12513

Rusdy M (2022). Chemical composition and nutritional value of urea treated rice straw for ruminants. Livestock Research for Rural Development 34: 657-666. Available online: https://www.lrrd.org/lrrd34/2/3410muhr.html

Syamsi AN, Ifani M, and Subagyo Y (2022). The Protein-Energy Synchronization Index of The Tropical Legumes for Ruminants. Jurnal Peternakan, 19(1), 29-37. DOI: http://dx.doi.org/10.24014/jupet.v19i1:15415

Tharmaraj J, Chapman DF, Hill J, Jacobs JL and Cullen BR (2014). Increasing home-grown forage consumption and profit in non-irrigated dairy systems. 2. Forage harvested. Animal Production Science 54(3): 234-246. DOI: https://doi.org/10.1071/AN12296

Thomas CS (2008). Efficient dairy buffalo production. DeLaval International AB, Tumba, Sweden.

Tsuji T (2021). The conventional and modern uses of water buffalo milk in the Philippines. Southeastern Philippines Journal of Research and Development 26(2): 1-21. DOI: https://doi.org/10.53899/spjrd.v26i2.152

Zucali M, Bacenetti J, Tamburini A, Nonini L, Sandrucci A and Bava L (2018). Environmental impact assessment of different cropping systems of home-grown feed for milk production. Journal of Cleaner Production 172: 3734-3746. DOI: https://doi.org/10.1016/j.jclepro.2017.07.048