Research Article

Developing Maize Silage and Ryegrass Blends based Fattening Ration for the Low-Input Small and Medium Scale Fattening Farmers in Pakistan

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Abstract | The growth rate of fattening animals under smallholder production systems in Pakistan is very low, partly because of the scarcity of good quality forages, and no or insufficient feeding of concentrates. The present study was carried out to address this issue, by developing maize silage and ryegrass forage blend based fattening rations. Five diets containing maize silage and ryegrass in the ratios of 30:70; 40:60; 50:50; 60:40 and 70:30 on dry matter (DM) basis in the forage mixture were evaluated in comparison with a control/traditional diet. A total of 18 calves were allocated to the six experimental diets according to a randomized complete block designed and the dietary groups were balanced for age, BW and sex. Data on intakes of DM, nutrients and metabolizable energy (ME), digestibility of DM and nutrients, body weight (BW) gain and body condition score (BCS) were recorded. The intake of all nutrients improved ($P < 0.05$) with the incorporation of blends of maize silage and ryegrass in the diet. Moreover, the intake of DM, organic matter (OM), and ME consistently increased ($P < 0.05$) with increasing maize silage inclusion levels (30 to 70%) in the forage blends, and the highest ($P < 0.05$) intake was recorded for diet containing 70% maize silage. Irrespective of the composition of the forage blend, the inclusion of forage blends in the diets increased ($P < 0.05$) average daily gain (ADG) and BCS as compared to the control diet. The minimum ($P < 0.05$) values of ADG (478 g/day) and BCS (3.00) were recorded for the control diet, and the maximum ($P < 0.05$) values of ADG (663 g/day) and BCS (5.75) were recorded for diet containing 70% maize silage in the forage blend. In conclusion, maize silage-based forage blends increased ADG of the calves by an average of 100 g/day as compared to the control diet, and the highest increase in ADG of 150 g/day was recorded for a blend containing highest proportion (70%) of maize silage.

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Introduction

In Pakistan, ruminant livestock are predominantly (> 80%) reared under subsistence small and medium scale productions systems (ESP, 2020-21). Although the animals kept for fattening and dairy purposes under the subsistence production systems have poor genetic potential for meat and milk production, however, due to poor nutrition the current productivity is also only one-third of their full genetic potential

(Habib *et al*., 2016). In addition, the rising interest of farmers to substitute local cows with cross-bred (local × exotic blood) in an attempt to enhance animal productivity has witnessed limited success in smallholder farms because of poor feed supply from mixed livestock-crop and extensive systems, which do not match with the high demand of quality feed for these animals (Habib *et al*., 2016). The increasing meat and milk, with concomitant decrease in area under pasture and fodder production and declining pasture carrying capacity, the role of livestock is increasingly changing from the traditional dual and non-food purposes towards more specialized functions aiming for high milk and meat production per animal. As such the demand for good quality feed is increasing rapidly (Khan *et al*., 2021). This has led to higher consumption of concentrate in commercial farms. The productivity, production efficiency and profitability of animals under smallholder production systems can be improved through the introduction of high yielding and highly nutritious fodders, and by optimizing their utilization through feeding of appropriate forage blends.

Forages in dry, ensiled and fresh forms are the natural, low-cost and often major fraction of ruminant livestock rations, especially in the conventional small scale farming systems. The development of good quality forage resources for the entire year and their optimum utilization will optimize the livestock productivity and profitability and will provide long-term sustainability to all types of livestock production systems in the country (Khan *et al*., 2021). Feeding of good quality forages also decreases the requirements for grain consumption, and thus reduces the food feed competition. Extensive research has demonstrated that feeding good quality forage to livestock can not only improve animals growth and milk production under the subsistence production systems, but also needed for optimum productivity, profitability, health and production efficiency of high-producing animals raised under the commercial dairy and fattening production systems (Habib *et al*., 2016; Shah *et al*., 2017; AIP, 2019).

The scarcity of good quality forages severely impedes livestock production in the country, particularly during the long forage scarcity period during the extreme winter and summer (Shah *et al*., 2017; Khan *et al*., 2021). Moreover, the rising demand for milk and meat has led to rapid intensification of the dairy and fattening industry over the past decade, which demands for efficient utilization of available land and feed resources. In this context, silage production from whole crop maize can play a key role to address this issue by ensuring continuous and uniform availability of premium quality forage throughout the year (Khan and Cone, 2017). Among the fodder crops grown in Pakistan, maize is the most profitable crop for high-quality silage production, because of its high dry matter (DM) production under a wide variety of environmental and soil conditions, high metabolizable energy (ME) content and good ensiling characteristics (Khan *et al*., 2015b; Khan and Cone, 2017). The hybrid maize currently used for silage production, is the most cost-effective forage crop for feeding high producing dairy and fattening animals around the world. The maize hybrids have been developed for almost all climatic zones that produces higher grain and overall biomass under a wide range of environmental and agronomical conditions. Moreover, the maize crop has good in-silo fermentation characteristics and high ME content (Khan *et al*., 2014). Moreover, replacing grass and legume forages with maize silage in the diet increases DM intake, which is critical for supporting high level of productivity (Khan *et al*., 2015b). Another study reported that replacing grass or grass silage in the ration with maize silage increases the yields of milk and milk components in dairy animals and average daily gain (ADG) in fattening animals (Keady *et al*., 2008). However, the benefit of feeding maize silage on animal productivity and farmers profitability, largely depends on the proportion of maize silage and other basal forage, and amount of concentrate in the diet (Khan *et al*., 2015b; Khan and Cone, 2017).

Maize silages are particularly rich in rapidly degradable energy. However, the crude protein (CP) concentration is lower (<8%) than that needed (>10%) for optimal rumen fermentation. For balancing the rapid energy supply from maize silage to the rumen, supplementation with rapidly degradable protein rich feed is needed. Ryegrass, when harvested in the late vegetative to early boot stage of maturity provides high concentrations of rumen degradable nitrogen (Van Vuuren *et al*., 1991). Moreover, much of the protein in ryegrass harvested at this stage of maturity is rapidly degraded in the rumen and can best complement maize silage that contain rapidly fermentable carbohydrates. The blend of maize silage and ryegrass will improve rumen microbial fermentation efficiency and nitrogen utilization by reducing ruminal ammonia-N and urinary-N excretion (Van Vuuren *et al*., 1993). Based on these information, mixed feeding maize with grass (ryegrass/Rhodes grass) for fattening animals is expected to increase animal productivi-

ty under small scale production system. Therefore, this study aimed to develop farm-grown nutritious forage crops (maize silage and ryegrass) based blend ration for the low-input small-and medium scale fattening farmers, to increase supply of energy and protein to the fattening animals, and optimize their utilization in terms of weight gain and feed use efficiency.

Materials and Methods

Selection of fattening farm and forage production

A small-scale fattening farm was selected for this study. Ryegrass was grown in five fields (34.8406° N, 72.2226° E) in vicinity of the selected fattening farm. Recommended sowing, agronomic, weed control and irrigation practices were followed. The first cut was taken after 60 days, and then after 7 weeks re-growth interval according to recommended practices. For the feeding trial the first re-growth crop was used, as the yield and nutritional value of first cut was variable. To ensure uniformity in maturity stage, the ryegrass in the five fields were sown on different dates, after calculating the requirements and estimated yields. Maize silage was produced at the farm as a single crop (cv. P30K08), sown at a seed density of 66,000/ha, and plant to plant space of 20 cm. The crop was grown under uniform standard agronomic and management condition. The crop was harvested at 35.0% targeted DM content, chopped (theoretical length of cut was 1 to 1.5 cm) and ensiled in bunker silos. To achieve optimum in-silo fermentation and post-ensiling stability, homofermentative inoculant was applied to fresh forage @ 2 mg/kg to supply 1×10^5 cfu/g of *Lactobacillus plantarum*. The chopped whole crop maize forage was compacted layer after layer in the bunker silo, with a heavy weight tractor and a wheel loader. The silages were kept airtight and sealed with 2 layers of 0.15 mm polyethylene plastic sheets and covered with a 20 cm thick sand load. The total silage-clamp was covered with a protection sheet being held down with sandbags.

Experimental design, animals and diets

For the feeding trial 18 fattening calves were selected from the herd based on body weight (BW), age, and sex. The calves were allocated to six diets according to a randomised complete block design (RCBD). The blocks were balanced for live BW, age and sex. The 6 diets were consisted of five blends of maize silage and ryegrass in the ratios of 30: 70; 40: 60; 50:50; 60: 40, and 70: 30 and a control conventional fattening diet which was consisted of maize fodder, wheat straw and concentrate (40:40:20 w/w) on dry matter basis. Known quantity forage blends were individually fed *ad-libitum* (10% more than previous day intake), two times a day. The refusals were recorded daily for each animal and analysed for DM content for two consecutive days each week. All animals had 24 h/d access to clean drinking water. The energy and protein supply to calves from each diet were matched with the requirement (NRC, 1996), by adjusting the proportion of fattening concentrate in the ration.

Sampling and data collection

Samples of ryegrass and maize silage were collected for two consecutive days during each experimental week. The samples were immediately transported to laboratory in cooling boxed and analysed for DM content. The remaining samples were pooled by feed type, mixed and subsample of 500 g were collected. The subsamples were air dried, ground to 1 mm particle size using Welly Mill and stored in plastic bottles for analysis of proximate nutrient profile, fiber composition and *in vitro* DM digestibility. The metabolizable energy (ME) content was estimated using the mathematical model of National Research Council (NRC, 1996). Data on feed offered, feed refused of individual calf were recorded daily throughout the experiment. Daily DM intake of individual calf was computed. The BW of individual calf was measures for two consecutive days before the start of the experiment, and then weekly, before morning feeding. Weekly and daily changes in total BW were computed.

Laboratory analysis

The samples of ensiled whole crop maize and ryegrass were analysed for proximate nutrient profile, fiber content and *in vitro* DM digestibility. The content of crude protein (CP, method # 984.13), ash (method # 942.05), DM (method # 930.15), acid detergent fiber (ADF, method # 973.18), ether extract (EE; method # 920.39) and acid detergent lignin (ADL; ADF Method # 973.18, followed by digestion with 72% sulphuric acid for 3 h) were analysed according to AOAC (2005). The neutral detergent fiber (NDF) content was determine using the method of Van Soest *et al.* (1991). The acid detergent-insoluble CP (ADICP) and neutral detergent insoluble CP (NDICP) contents were determined using the methods of Licitra *et al.* (1996). The non-fiber carbohydrate (NFC) and total carbohydrate (CHO) contents were computed

according to NRC (2001).

$$NFC = 100 - (NDF - NDICP) - CP - EE - Ash$$
$$CHO = 100 - CP - EE - Ash$$

The contents of starch was determined using the kits (Catalog # K-TSTA, K-AMYL, K-BGLU) of Megazyme (Wicklow, Ireland). The *in vitro* DM digestibility (DMD) was measured using the two-step *in vitro* procedure of Tilley and Terry (1963).

Feed samples were analysed for the rate and extent of ruminal degradation DM and CP using *in situ* technique (Ørskov and McDonald, 1979). The energy values of total digestible (td) fatty acids (tdFA), td NFC (tdNFC), td CP (tdCP), td NDF (tdNDF), td nutrients (TDN), digestible energy (DE) and ME were estimated from the chemical composition using the following mathematical equations of NRC (1996). The ME was calculated as follows:

$$ME = DE \times 0.82$$

The digestible energy (DE) was calculated as follows:

$$DE = \left(\frac{NFC}{100}\right) \times 4.2 + \left(\frac{tdNDF}{100}\right) \times 4.2 + \left(\frac{tdCP}{100}\right) \times 5.6 + \left(\frac{tdFA}{100}\right) \times 9.4 - 0.3$$

Where;
NFC: Non fiber carbohydrates; tdNDF: Total digestible NDF; tdCP: Total digestible CP; tdFA: Total digestible fatty acids, and these fractions were computed using the following models:

$$tdNDF = 0.75 - [(NDF - NDICP) - ADL] \times \left[1 - \frac{ADL}{(NDF - NDICP)}\right]$$
$$tdCP = \left[1 - \left\{0.04 \left(\frac{ADICP}{CP}\right)\right\}\right] \times CP$$
$$tdFA = (Cfat - 1) \times 2.25$$

Rumen degradable protein (RDP) and rumen undegradable protein (RUP) were determined using equations developed by NRC (2001).

$$RDP = A + B \times \frac{Kd}{Kd + Kp}$$

And

$$RUP = A + B \times \frac{Kp}{Kd + Kp}$$

Where;
A: Soluble protein fraction; B: Potentially degradable protein fraction; C: Undegradable protein fraction; K_p: Rumen passage rate (0.06/hour); k_d: Rate of degradation of B fraction.

Body weight and Body Condition Score

The BW of the experimental calf was recorded for two consecutive days before morning feeding at the start of the experiment and then each experimental week using and electronic cattle weighing system. Body condition score (BCS) was estimated fortnightly using the guidelines of NRC (1996). The BCS experimental calf could be easily divided into one of four categories: thin (BCS 1 to 3), borderline (BCS 4), optimum (BCS 5 to 7) or fat (BCS 8 and 9).

Statistical analysis

The effects of forage blend on DM intake, gain in BW, BCS, ADG and economics parameters were analysed with the mixed model procedure of Statistical Analysis System (SAS Inst., Inc., Cary, NC) using repeated measure analysis of variance. Fixed effects in the model were forage-blends, and random effect were block/replication. The model was:

$$Yijk = \mu + MRM_i + \epsilon ijk$$

Where;
Yijk: Response variable; μ: Overall mean; MRMi: Fixed effect of maize silage and ryegrass blends; Єijk: Random error.

For parameters with significant effects ($P < 0.05$) of forage blend post-hoc-analyses were conducted to compute pair-wise differences in the respective means using the Tukey–Kramer test. An additional SAS software "pdmix 800 SAS macro" was used to obtain means with different letters.

Results and Discussion

Chemical profile of forages used in the experimental rations

Data on chemical composition of the of maize silage and ryegrass are summarized in Table 1. The DM content of maize silage was 34.8%, which was close to the targeted DM content. The chemical composition showed that maize silage had excellent nutritional and fermentation quality as reflected by the high starch (34.1%) and lower NDF (38.3%) contents, and high DMD (72.1%), TDN (67.6%), ME (2.90 Mcal/kg) and the pH value (3.59). The ryegrass forage also had good nutritional value as reflect by high CP content (14.4% DM) and high DMD (63.4% DM), TDN (60.3%) and ME (2.17 Mcal/kg).

Table 1: *Chemical composition of maize silage and ryegrass used in the experiment.*

Measurements	Maize silage (Mean ±SD)	Ryegrass (Mean ±SD)
Basic chemical profile		
Dry matter (DM) % fresh matter	34.8 ± 0.90	17.9 ± 1.81
Ash % of DM	3.91 ± 0.31	8.12 ± 0.44
Crude fat % of DM	3.42 ± 0.40	3.39 ± 1.22
Crude protein (CP) % of DM	7.32 ± 0.25	14.4 ± 1.84
Protein chemical profile		
Soluble CP (% CP)	38.9 ± 1.10	41.1 ± 1.32
NDICP (% CP)	11.7 ± 0.78	12.32 ± 0.65
ADICP (% CP)	5.51 ± 0.65	5.52 ± 0.52
Rumen degraded protein (% CP)	65.5 ± 0.92	74.1 ± 1.16
Rumen undegraded protein (% CP)	34.5 ± 0.92	25.9 ± 1.16
Carbohydrate chemical profile (% DM)		
Acid detergent lignin	3.19 ± 0.38	9.15 ± 0.65
Acid detergent fibre	22.8 ± 1.31	33.8 ± 1.78
Neutral detergent fibre	38.3 ± 1.80	53.2 ± 2.70
Starch	34.1 ± 0.92	1.83 ± 0.29
Non-fibre carbohydrates	37.2 ± 0.90	22.29 ± 0.22
Energy values		
Total digestibility nutrients (%)	67.6 ± 0.90	60 .3 ± 0.98
Metabolizable energy (Mcal/kg)	2.90 ± 0.41	2.17 ± 0.43
Ddigestibility		
DMD (in vitro) % of DM	72.1 ± 1.52	63.4 ± 2.12
Ffermentation quality		
pH	3.59 ± 0.11	
NH_3-N% of total N	7.90 ± 1.10	

ADICP: *acid detergent insoluble CP;* **NDICP:** *neutral detergent insoluble CP;* **DMD:** *dry matter digestibility;* **NH_3-N:** *ammonia-N.*

Intake of dry matter, nutrients and metabolizable energy

Table 2 summarises data on the effect of different blends of maize silage and ryegrass on intake of DM, nutrients and ME of the fattening calves in comparison with control diet. Except NDF, the intake of all nutrients improved (P < 0.05) with addition of ryegrass and maize silage blends in the diets. The intake of DM, organic matter (OM), and ME increased (P < 0.05) with increasing inclusion levels (30 to 70%) of maize silage in the forage blends. The highest (P < 0.05) intake of DM (4.25 kg/day), OM (2.54 kg/day) and ME (12.07 Mcal/kg) was recorded for diet containing 70% maize silage. While the lowest (P < 0.05) intake of DM (3.85 kg/day), OM (3.93 kg/day) and ME (5.57 Mcal/kg) was recorded for the control diet.

Table 2: *Effect of experimental diets based on different blends of maize silage (MS) and ryegrass on intake of dry matter, nutrients and metabolizable energy (ME) of the fattening calves in comparison with control diet.*

Diets	Intake (kg/calf/day)				ME (Mcal/kg)
	DM	OM	CP	NDF	
Control	3.85^{c}	3.54^{b}	0.09^{c}	2.13	5.57^{c}
MS30	3.87^{c}	3.51^{b}	0.43^{a}	2.28	9.08^{b}
MS40	3.90^{bc}	3.56^{b}	0.42^{ab}	2.25	11.39^{b}
MS50	3.92^{bc}	3.60^{b}	0.39^{ab}	2.24	11.29^{b}
MS60	4.10^{ab}	3.80^{ab}	0.41^{ab}	2.38	11.80^{ab}
MS70	4.25^{a}	3.93^{a}	0.38^{b}	2.32	12.07^{a}
SEM	0.11	0.1	0.01	0.06	0.5
Significance	*	***	***	NS	***

*Different superscripts with in columns are significantly (P < 0.05) different. The MS0, MS30, MS50 and MS60 and MS70 means 0, 30, 50, 60 and 70% maize silage in the ryegrass and maize silage forage blend on dry matter basis. DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fibre; SEM, standard error of the means; NS, non-significant (P > 0.05) *, P < 0.05; ***, P < 0.001*

Table 3: *Effect of different blends of maize silage (MS) and ryegrass on digestibility of dry matter, nutrients in the fattening calves.*

Diets	Digestibility (g/100 g)			
	DM	OM	CP	NDF
Control	44.17^{b}	45.62^{c}	56.22^{d}	47.8^{b}
MS30	63.07^{a}	64.44^{a}	65.98^{a}	54.8^{a}
MS40	63.31^{a}	64.18^{a}	65.27^{ab}	55.0^{a}
MS50	62.38^{a}	63.46^{a}	64.01^{bc}	54.5^{a}
MS60	62.62^{a}	63.58^{a}	63.26^{c}	54.7^{a}
MS70	62.21^{a}	63.57^{a}	62.23^{c}	54.5^{a}
SEM	1.28	0.83	0.68	0.77
Significance	***	***	***	***

*Different superscripts with in columns are significantly (P < 0.05) different. The Control, MS30, MS50 and MS60 and MS70 means 0, 30, 50, 60 and 70% maize silage in the ryegrass and maize silage forage blend on dry matter basis. DM, dry matter; OM, organic matter; CP, crude protein; NDF, neutral detergent fibre; SEM, standard error of the means; ***, P < 0.001*

Digestibility of dry matter, nutrients and metabolizable energy

Data on the effect of different blends of maize silage and ryegrass on digestibility of DM, nutrients and ME of the fattening calves in comparison with control diet is presented in Table 3. Compared to control the digestibly of all measured nutrients and ME were higher (P < 0.05) in calves fed with the maize silage

and ryegrass blends. However, the digestibly of all measured nutrients did not vary (P > 0.05) among the different blends of maize silage and ryegrass. Maximum (P < 0.05) CP digestibility was recorded for forage blend containing 70% ryegrass and 30% maize silage. Further comparison showed that CP digestibility decreased (P < 0.05) with increasing inclusion levels of maize silage in the diet.

Table 4: *Effect of experimental diets based on different blends of maize silage (MS) and ryegrass on body weight changes and body condition score of fattening calves in comparison with control diet.*

Diets	Weight (kg/calf/day)			BCS
	IBW	FBW	Gain	
Control	118.00	157.82^{e}	40.15^{d}	3.00^{c}
MS30	118.33	160.10^{d}	42.77^{d}	4.00^{b}
MS40	118.14	164.44^{c}	46.98^{c}	4.50^{ab}
MS50	118.33	165.25^{bc}	48.78^{bc}	5.00^{b}
MS60	118.36	168.71^{b}	51.24^{b}	5.75^{a}
MS70	118.67	173.62^{a}	55.73^{a}	5.75^{a}
SEM	3.48	2.34	1.91	0.4
Significance	NS	***	***	***

*Different superscripts within columns are significantly (P < 0.05) different. The Control, MS30, MS40, MS50, MS60 and MS70 means 0, 30, 40, 50, 60 and 70% maize silage in the ryegrass and maize silage forage blend on dry matter basis. IBW, initial body weight; FBW, final body weight; Gain, total weight gain; BCS, body condition score; SEM, standard error of the means; NS, non-significant (P > 0.05); ***, P < 0.001*

Effect of different blends of maize silage and ryegrass on changes in body weight and body condition score of fattening calves

Table 4 presents data on the effect of different blends of maize silage and ryegrass on initial body weight (IBW), final body weight (FBW), BW gain and BCS in comparison with control group. The weekly changes in mean BW of calves fed with the different experimental diets in comparison with control diet is shown in Figure 1. There were no differences (P > 0.05) among the IBW among the dietary groups, ranging from 118.00 to 118.67 kg. Diet composition altered (P < 0.001) FBW among the dietary groups. The minimum (P < 0.05) FBW (157.82 kg) was recorded for control diet and the maximum (P < 0.05) FBW (173.62) was recorded for diet containing 70% maize silage in the forage blend. Among the forage blends-based diets, the FBW of the calves improved (P < 0.05) consistently with increasing level (30 to 70%) of the maize silage in the forage blends. Similar to the FBW, the minimum (P < 0.05) of BCS (3.00) was recorded for the control diet, while the maximum (P < 0.05) BCS (5.75) was recorded for diets containing 60 and 70% maize silage. Among the forage blends-based diets, the BCS of the calves improved (P < 0.05) consistently with increasing level of silage in the forage blends from 30 to 70%.

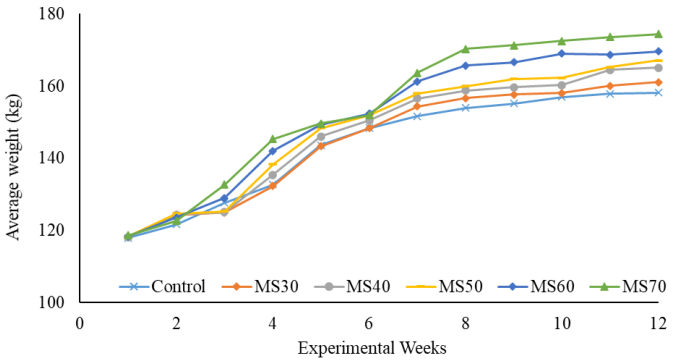

Figure 1: *Weekly changes in average weight of calves in response to experimental diets based on different blends of maize silage and ryegrass in comparison with control diet. Diet MS30, MS40, MS50, MS60 and MS70 contained 30, 40, 50, 60 and 70% maize silage in the maize silage and ryegrass blends.*

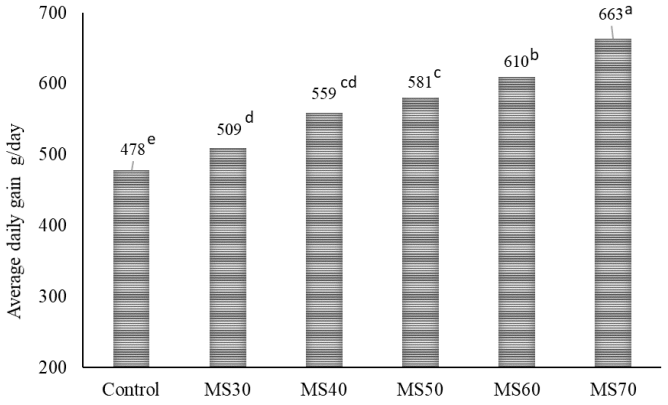

Figure 2: *Average daily gain of calves in response to experimental diets based on different blends of maize silage and ryegrass in comparison with control diet. Diet MS30, MS40, MS50, MS60 and MS70 contained 30, 40, 50, 60 and 70% maize silage in the maize silage and ryegrass blends.*

Effect of different blends of maize silage and ryegrass on changes in average daily gain of fattening calves

Figure 2 shows data on the average daily gain of calves in response to feeding of the experimental diets based on different blends of maize silage and ryegrass in comparison with control diet. Inclusion of the maize silage and ryegrass blends in the diet increased (P < 0.001) ADG, irrespective of the proportion of ryegrass and maize silage in the diet. However, the maximum (P < 0.05) ADG (663 g/day) was observed for the diet containing 70% maize silage. While the minimum (P < 0.05) ADG (478 g/day) was observed for control diet.

There is an increasing pressure on the sustainability of animal production systems in industrialized as well as in developing countries, due to the declining availability and higher prices of traditional feeds, and a growing food-feed-fuel competition (Alexandratos and Bruinsma, 2012). To address this issue, a maximum local recycling and re-utilization of nutrients by ensuring optimum use of indigenous plant biomass is a must. To achieve this objective, an intensive and efficient use of biomass from the fodder resources, agriculture crops residues, agro-industrial by-products and other non-conventional feed resources such as fruits and vegetable wastes are must. Extensive research has shown that the bottleneck to the lower productivity of fattening animals in Pakistan is the low-quality and availability of good quality forages (Sarwar *et al*., 2002; Khan *et al*., 2020). As such the introduction of high yielding and highly nutritious fodder crops and their efficient utilization in fattening farming can increase their productivity and profitability on sustainable basis, particularly in the predominantly (> 80%) smallholder's production systems in Pakistan. In this context, this study was conducted to produce the first dataset on the effect of high yielding and highly nutritious fodders, maize silage and ryegrass, blends-based rations on the productivity and profitability of fattening animals under smallholder production systems, to design a sustainable viable enterprise for the smallholders. In this trail, diets based on different blends of maize silage and ryegrass in the ratios of 30:70; 40:60; 50:50; 60:40 and 70:30 were evaluated in comparison with a control (routine) diet. The results revealed that all maize silage-based forage blends increased daily weight gain of the calves by an average of 100 g/day, and the highest increase in daily weight gain of 150 g/day was recorded for a blend containing highest proportion (70%) of maize silage. The improved FCR (6.50 kg) in terms of DMI per kg BW gain in MS70 can be attributed to the higher digestibility of nutrients and increased BW gain in the diets with higher levels of maize silage. This well-designed, systematic study developed low-cost, forage-blend based rations for fattening animals with year-round availability, providing prospects for the much-needed long-term sustainability of the low-input small-and medium scale fattening farmers in the increasingly competitive specialized/ commercialized livestock production systems in Pakistan. Moreover, the newly developed forage blends increased feed-use efficiency, decreased feed cost, increased animal's productivity under the smallholder production systems, and indirectly decreased the dependency on expensive concentrates.

According to the Meta-Analysis of (Khan *et al*., 2015a) on the nutritional quality of maize silages, the silage used in the present study had good nutritional and fermentation quality, as reflected by the high starch (34.1%) and lower NDF (38.3%) contents, high values of DM digestibility (72.1%), TDN (67.6%) and ME (2.90 Mcal/kg), and lower pH value (3.59). The ryegrass forage also had good nutritional value as reflect by high CP content (14.4% DM) and high DMD (63.4% DM), TDN (60.3%) and ME (2.17 Mcal/kg), which are consistent with literature values (Taweel, 2004; Baldinger *et al*., 2011; Özelçam *et al*., 2015).

The intake of all nutrients increased with the inclusion of maize silage and ryegrass in the diets. When harvested in the late vegetative to early boot stage of maturity, ryegrass provides high concentrations of rumen degradable nitrogen and highly digestible fibre to animal (Van Vuuren *et al*., 1991), that support high DM intake. Moreover, extensive research has established that the inclusion of maize silage in the grass/legume-based diets also increases DM intake (Allen, 2000; Keady *et al*., 2000; Phipps *et al*., 2000). The small particle size, greater fermentation rate and clearance from the rumen, all contribute to the greater DM intake when maize silage is fed to the cows. The blend of maize silage and berseem further ensure a balanced supply of energy and NH_3-N to the microbes, optimizing ruminal fermentation process. Comparison of the forage blends revealed that the DM intake, linearly increased with increasing levels of maize silage in the ryegrass-maize silage blends. Ryegrass is a good quality grass, with high digestibility, even then the DM intake and milk yield increased with the addition of silage in ration. Higher DM intake with the silage in the forage blend is an important nutritional characteristic of maize silage, due to which the addition of silage supported higher productivity in dairy and fattening animals (Khan *et al*., 2015b). The increase in DM intake with the addition of maize silage is attributed to its lower fibre and higher starch contents, and the more balanced supply of both fermentable carbohydrates and ammonia-N from the blend of ryegrass and maize silage.

Similar to the increase in DM intake, the inclusion of maize silage and ryegrass in the diets increased ADG and BCS of the calves. Further comparison of

the forage blends revealed that weight gain and body condition score of the calves linearly increased with increasing levels of maize silage in the ryegrass-maize silage blends. Feeding a blend of maize silage and ryegrass to animal has greater energy and microbial protein availability to support higher level of productivity (Cooke *et al*., 2008). Our findings showed that a blend of 70% maize silage and 30% ryegrass of best complement each other in terms of energy and protein supply to fattening calves as reflected in intakes of DM and ME, and weight gain and BCS of the calves. Much of the protein in ryegrass harvested at vegetative stage of maturity is rapidly degraded in the rumen (Van Vuuren *et al*., 1993), that could partly explain the optimum performance of calves fed with diet containing 70% maize silage and 30% ryegrass in the blend. Developing strategic blend of maize and ryegrass, on the basis of our findings is expected to increase productivity of fattening animals under small scale production system.

Conclusions and Recommendations

Diets based on different blends of maize silage and ryegrass in the ratios of 30:70; 40:60; 50:50; 60:40 and 70:30 in fattening rations increased the intake of all nutrients, BW, ADG and BCS as compared the control diet. Comparison of the forage blends revealed that with increasing inclusion levels (30 to 70%) of maize silage the intakes of DM, OM and ME consistently increased, causing a consequent increase in BW gain, ADG and BCS. The minimum values of FBW (157.82 kg), ADG (478 g/day) and BCS (3.00) were recorded for the control diet, and the maximum values of FBW (173.62 kg), ADG (663 g/day) and BCS (5.75) were recorded for diet containing 70% maize silage in the forage blend. Overall, these results revealed that all maize silage-based forage blends increased ADG of the calves by an average of 100 g/day as compared to the control diet, and the highest increase in ADG of 150 g/day was recorded for a blend containing highest proportion (70%) of maize silages.

Novelty Statement

In Pakistan maize silage production has increased tremendously over the last few years. However, information of the optimal utilization of maize silage in dairy and fattening rations, particularly under the small-scale production system is scarce. To our knowledge this is the first study on the systematic on the optimum utilization of maize silage in fattening ration, in terms of silage animal performance, by feeding different blends of maize silage and ryegrass. The findings of the current study demonstrated that optimum utilization of maize silage increases average daily gain of the calves, which could in turn decrease the requirements for feeding of concentrates.

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Author's Contribution

Khalid Farooq: Executed the experiment, collected, compiled and analyzed data and wrote the first draft.
Muhammad Tahir: Conceptualization of the study, writing review and editing and supervision of the study.
Nazir Ahmad Khan: Funding acquisition, supervision, conceptualization and project administration.

Conflict of interest
The authors have declared no conflict of interest.

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