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Research Article

Supply chain analysis of silage in Chitwan district of Nepal

Sanjiv Subedi[1*], Krishna Prasad Timsina[1], Sudha Sapkota[1] and Jyoti Chhetri[2]

[1]Nepal Agricultural Research Council, National Agricultural Policy Research Centre, Khumaltar, Lalitpur, Nepal
[2]Ministry of Agriculture, Land Management and Cooperatives, Gandaki Province, Pokhara, Nepal
[*]Correspondence: sanjiv.subedi@gmail.com
[*]ORCID: https://orcid.org/0000-0002-8084-008X

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ABSTRACT

Silage, anaerobically fermented green fodder, is valued worldwide as a source of animal feed during lean months. No studies have yet been documented exploring the supply chain of silage and production economics of fodder used. Also, identification and prioritization of the major problems associated with fodder maize production, silage production and marketing is necessary. Chitwan district was purposively selected for this study as there are a greater number of commercial dairy cattle farms and silage-making agro-industries. A field survey of sample size 90 (using simple random sampling technique) and 1 FGD was conducted among the fodder maize growing farmers; moreover, Key Informant Interview was taken with the owner of six different silage producing farms during the time period between September, 2023 to February, 2024. The average productivity of the fodder maize was 539 qt/ha. The average land holding of the farmers growing fodder maize was found to be 0.38 ha. Moreover, the average price of the fodder maize was estimated NRs.345/qt. The positive gross margin and benefit cost ratio (BCR) greater than one showed both fodder maize production and silage production profitable and financially viable enterprises. Indexing identified the inadequate availability of fertilizers in time and the low price of fodder maize in the market as the first major problems associated with fodder maize production and marketing respectively. The role of cooperatives seemed to be important in the backward and forward linkages of silage as cooperatives were found to be closely associated with the marketing of fodder maize and silage as well. Assuring the timely availability of fertilizers, quality seed of suitable varieties and irrigation facilities must be the priority areas of government intervention to enhance the production of fodder maize and silage. Moreover, price favor for the farmers, prioritizing the development of marketing channels, assuring the availability of market information, developing the transportation and storage facilities seemed to be primary areas of intervention to promote and strengthen the supply chain of silage. Assessing the demand for silage and exploring the more sustainable value chain could be an important area for further research.

Keywords: benefit-cost ratio, fodder maize, silage, supply chain

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INTRODUCTION

Silage is usually defined as a specific technological process of processing and preserving certain fodder plants using lactic acid bacteria, which retains the natural properties and nutritional value of plants (Allen *et al.*, 2003). Silage is a fermented feed resulting from the storage of high-moisture crops such as maize, grasses, and Napier under anaerobic conditions. It is the fodder which is conserved by reducing pH through natural anaerobic fermentation and is used for feeding during scarcity periods, drought or floods and for utilizing surplus forage. Silage can ensure the supply of quality forage in the lean months and during droughts (Gyawali *et al.*, 2018). The crisis of animal feed during the winter season causes nutritional stress and reduces the capacity to resist cold stress; silage is valued throughout the world as a source of animal feed during lean months (Ragothaman *et al.*, 2010). Silage preserves close to 85 per cent of the nutritional value of the crops. Land under fodder cultivation is emptied, and immediately it could be used for plantation of other crops. The use of corn silage is increasing because of its wide range of benefits such as low harvesting cost, minimum production risks, high yields, high energy intake for livestock, increased lactation length, stocking rate digestibility, palatability and storage ability (Schroede, 2004; Ferraretto *et al.*, 2018). Maize is the most suitable fodder for making silage as maize is a heavy feeder plant, it contains starch soluble carbohydrates and has high biomass production. It is rich in metabolizable energy and supports higher DMI (dry matter intake) and milk yield. Harvesting maize silages at a DM (dry matter) content between 300 and 350 g kg−1 and feeding in combination with grass silage results in a higher milk yield for dairy cows (Khan *et al.*, 2014). Maize is grown in different geographical regions ranging from Terai to mid hill of Nepal. As per the reports of MOALD (2022), the area, production and yield of maize in Nepal in the year 2020/21 have been reported 9,79,776 ha, 2,997,733 mt and 3.06 mt/ha respectively.

The overall contribution of the agriculture, livestock and forestry sector to the national GDP is 15.6, 6.23, 1.68 percent respectively. Moreover, of total contribution from the livestock sector to national GDP (6.23 %), the contribution of sub-sector, dairy and domestic animals farming, is the highest (5.57 %). The total milk production in Nepal in the year 2020/21 has been reported 2,479,899 mt; moreover, that of in Chitwan district was 52749 mt. The total number of milking cows and buffaloes in Nepal was 1,209,041 and 1,630,642, while that of in Chitwan district was 17,811 and 25,399 respectively (MOALD, 2022). The growing dairy and agro-processing industries in the urban and peri-urban areas have resulted to establishment of commercial dairy animal and other livestock farms in those areas. The roughages and fiber which are found in green grasses, fodder and forages are important nutrients that must be made available in the ration feed to the dairy animals. For ruminant dairy animals, year-round, two-third proportion of the daily ration should be the fiber and roughages (Banerjee, 1991); however, growing green grasses and fodder for commercial farms in urban and peri-urban areas is a big challenge due to limited farmland. To meet this nutritional requirement, those livestock farms must include silage in the daily ration of dairy animals. Optimization of roughage to concentrate ratio improves the efficiency of nutrient utilization. It has been revealed that for the most economical milk production under average conditions, more than two-thirds of the ration fed to the dairy ruminants should be the roughages (Arti, 2018). Moreover, it has been reported that producers of corn silage are mostly larger agricultural farms focused on cattle production; even the highest quality corn silage could be more economic than the concentrated feed (Alen *et al.*, 2021). No studies have yet been documented exploring the supply chain map of silage and production

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economics of fodder used. Also, identification and prioritization of the major problems associated with fodder maize production, silage production and marketing is necessary. In this context, this research aims to address these research gaps.

METHODOLOGY

Selection of the study area

Chitwan district was purposively selected for this study as there is more commercial dairy cattle farms and dairy farmers and silage-making agro-industries known as per consultation with agriculture scientists of National Fodder and Pasture Research Program, Lalitpur and National Maize Research Program (NMRP) and National Cattle Research Program (NCRP) and Veterinary Hospital and Livestock Service Expert Centre (VHLSEC) located at Chitwan district. The study sites were Gitanagar, Shantinagar, Kesharbag, Indrapuri and Parasanagar of Bharatpur Metropolitan City which were selected after consulting with the experts, fodder-growing farmers and silage entrepreneurs. Also, a Key Informant Interview (KII) was done with the selected silage producing farm owner located at Ratnangar, Khairehani Haraiya and Gitanagar.

Sampling frame, Sampling technique and Sample size

The sampling frame of the fodder maize-growing farmers of Chitwan was prepared taking the support of progressive farmers, VHLEC technical experts and silage entrepreneurs. The simple random sampling technique was used to select the sample from the sampling frame. All total 90 sample farmers were selected for the purpose of the study which was 12% of the target population. Moreover, owners of the six different silage-producing farms were selected for KII to collect the information on silage production and marketing.

Methods and techniques of data collection

Both primary and secondary sources were used to collect the necessary information required for this study. Primary information was collected using the tools and techniques viz. a field survey, one Focus Group Discussions (FGD) and six KII conducted during the period of September, 2023 to February, 2024. The pre-tested interview schedule, and checklist were used to collect the information from the fodder maize growing farmers while the checklist was used to collect the information from the silage-producing farms having KII with the farm owner/manager and experts. Secondary information was collected by reviewing the relevant publications.

Methods and techniques of data analysis

Data entry and analysis were done using computer software packages like: Statistical Package for Social Science (SPSS) and Microsoft Excel (MS Excel) based on the suitability of the data. The following analyses were performed.

Costs and Returns associated with fodder maize production

The total variable cost of fodder maize production was calculated by summing the field preparation cost, seed cost, fertilizer cost, human labor cost, herbicides and pesticides cost and irrigation cost incurred in the production. Returns was simply calculated by multiplying the total quantity of biomass by price per unit.

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Profitability associated with fodder maize production

The profitability associated with the fodder maize production is described by calculating the gross margin and benefit-cost ratio (BCR).

Gross Margin

The gross margin was calculated by deducting the total variable cost from the gross return. The gross margin was calculated by using the method given by Olukosi *et al.* (2006) using the following formula;

Gross margin (NRs./ha) = Gross return (NRs./ha) - Total variable cost (NRs./ha) (1)

Benefit Cost Ratio

The undiscounted benefit cost ratio was estimated as a ratio of gross return and total variable cost. The benefit cost ratio was calculated by using the formula:

$$\text{Benefit cost ratio (BCR)} = \frac{\text{Gross return (NRs./ha)}}{\text{Total variable cost (NRs./ha)}} \quad \text{..... (2)}$$

The above formula to calculate the gross margin and BCR has been used by Subedi *et al.* (2020) to estimate the profitability associated with the rice production.

Assessment of economics of production and marketing of silage through KII among the silage-producing farm owner/manager

The necessary information on cost, benefits, marketing channel and other variables associated with silage production and marketing was obtained through the KII with six silage entrepreneurs performed with a checklist.

Supply chain map

The major marketing channels used in fodder maize marketing were identified and the market actors involved in the marketing of fodder maize were explored. The supply chain map was sketched showing the actors, enablers and functions. The backward and forward linkages associated with fodder maize and silage are reflected in the supply chain map. The map was sketched of based on information obtained from the field survey (conducted among the fodder maize growing farmers), FGD (among fodder maize growing farmers) and KII with the experts and silage entrepreneurs.

Problems associated with the fodder maize production

The major problems associated with the production of fodder maize were identified through FGD. Moreover, farmers' opinions regarding the severity of those problems were taken during the field survey. The indexing/Scaling technique was applied to construct an index for prioritizing the problems as per farmers' perception using MS-Excel. The indexing technique has been used to rank the problems associated with agricultural crop production in many studies (Shrestha and Shrestha 2017; Subedi *et al.*, 2019). Farmer's perceptions to the different production problems ranked by using five-point scales. The formula used to determine the index for intensity of various problems is:

$$I_{prob} = \sum(S_i f_i)/N \quad \text{..... (3)}$$

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where, I_{prob} = index value for intensity of the problem
Σ= summation
S_i = scale value at i^{th} intensity/severity
f_i= frequency of the i^{th} severity
N= total no. of the respondents = Σf_i
where, I_{prob}= index, $0 < I < 1$

RESULTS AND DISCUSSION

Cost of fodder maize production

The total cost of fodder maize production was calculated NRs.133474 /ha. Human labour cost was the major cost item having the highest share in the total cost (36.1%) followed by FYM (16.2%), seed (13.9), chemical fertilizers (13.7%), tractor power (7.3%), pesticides/herbicides (7.2%) and irrigation (5.7%) (Table1). A study examining the cost efficiency of maize production in Chitwan, Nepal also stated that the highest share in the production cost of maize was from the use of human labour (Paudel and Matsuoka, 2009).

Table 1: Average variable cost of fodder maize production

S.N.	Costs items	Mean (NRs./ha)	Percentage of total cost
1.	Seed	18533	13.9
2.	Chemical Fertilizers	18330	13.7
3.	Farm Yard manure cost	21617	16.2
4.	Human labour	48227	36.1
5.	Tractor power	9784	7.3
6.	Pesticides/ herbicides	9480	7.2
7.	Irrigation	7503	5.6
	Total variable cost	**133474**	100

Source: Field survey, 2023

Returns from fodder maize production

The average total returns from fodder maize production per hectare was calculated NRs.185955 which was simply calculated by averaging the total returns calculated by multiplying the quantity of fodder maize produced with the price of the fodder maize.

Price and productivity

The average productivity of the fodder maize was calculated 539 qtl/ha. The average land holding of the farmers growing fodder maize was estimated 0.38 ha. The mostly cultivated varieties of maize for silage purposes (fodder maize) were: Rampur-10, Rampur-12, Pratap, M006, M007, CP808, CP 838. Moreover, the average price of the fodder maize was estimated NRs.345/qtl. The price of the fodder used for silage-making purposes has been reported as INR. 300/qtl. in Kharif and it touched to INR. 400/qtl. in summer in Gujrat, India (Grover & Kumar, 2012).

Gross margin and benefit-cost ratio

The gross margin of fodder maize production in the study area was calculated as NRs. 52481/ha. The benefit-cost ratio was estimated 1.4; which means if 1 rupee is invested; it will give 1.4 rupee returns. The positive value of gross margin and benefit-cost ratio being greater than one indicates the financial viability of fodder maize production in the study area (Table

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2). A study conducted on hybrid maize farming in Morang and Sunsari districts estimated the gross margin of NRs.58310/ha (Adhikari *et al.*, 2019). A study conducted in the Sindhuli district of Nepal estimated the B: C ratio of maize production to be 1.20. Also, research carried out in Dang, Nepal revealed that maize production was profitable as indicated by the B: C ratio of 1.52 (Poudel *et al.*, 2023). The profitability analysis of fodder maize production in Gujarat, India during the kharif season revealed a net return of INR. 21954/ha. Moreover, in Madhya Pradesh, India, the fodder crop (berseem) production was profitable where an average fodder grower invested INR.13835.66/ha and received INR. 52521.47/ha which showed the benefit-cost ratio 3.7 (Grover & Kumar, 2012).

Table 2: Financial indicators of fodder maize production in the study area

Indicators	Average value (NRs./ha)
Total variable cost	133474
Total returns	185955
Gross margin	52481
Benefit-cost ratio	1.4

Source: Field survey, 2023

Marketing channels of fodder maize revealed from the study area

Various actors in the marketing channel are facilitating the transfer of goods from producer to consumer. The different marketing channels used for fodder maize marketing revealed in the study area are mention below.

1. Fodder maize growing farmer-Cooperatives-Silage company
2. Fodder maize growing farmer-Silage company
3. Fodder maize growing farmer- Collector-Silage company
4. Fodder maize growing farmer- Own farm for silage making

It has been revealed that in Gujarat, India, fodder is generally sold by producers through one marketing channel, namely Producer-Local Trader-Consumer (Grover & Kumar, 2012). Moreover, a study conducted in Dang, Nepal, identified different marketing channels: Channel-I (Producer – Collector – Wholesaler - Consumer), Channel-II (Producer– Collector-Consumer), Channel-III (Producer-Collector-Feeding Mills) and Channel-IV (Producer-Consumer) (Yadav *et al.*, 2023).

Findings revealed from KII among the silage-producing farms

The silage-producing farms bought the fodder maize from the farmers at different rate as per season: Rs.4.5/kg (Oct/Nov), Rs.5-5.5/kg (Dec/Jan/Feb/March) and Rs.3-3.5/kg (April, May, June). The average variable cost of production for silage has been revealed as Rs.11.5/kg and the average selling price Rs.13.5/kg which indicates profitability and financial viability of silage firms. The silage bundle weight varies from 40 kg to 80 kg. The weight of the total silage produced was found to be nearly 85-90% of the weight of green fodder maize. The maximum sales of silage are in the months: Oct, Nov, Dec, Jan. High volume sales (60-80 qtl/day), while minimum in the months: Baisakh, Jestha, Asar, Shrawan (30-40 qtl/day). In the world scenario, a study revealed that corn silage production was conducted on 35 hectares of land in Bosnia and Herzegovina, resulting in a total output of 781 tons, which turned out to be an average of 22 tons per hectare (BHAS, 2021). Similarly, in Iran, it was found that the cultivation area of

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silage crops was around 280,000 hectares with an average production of 70 t/ha (Ministry of Jihad-e-Agriculture of Iran, 2018). A study carried out in Bosnia and Herzegovina found that in the initial three years, the production costs of silage increase and then in the later three years, they decrease. Based on their study, it was determined that the largest share of production cost was incurred in minerals and fertilizers (26.1%) which was followed by fuels for mechanization (14.9 %) and seeds of corn (14.7 %), whereas depreciation costs made up the smallest share (1.2 %) (Falan *et al.*, 2021). The study also determined the total costs of silage production in different years where the highest total cost as well as total cost/ha were in 2016 (592.489 EUR and 1.481 EUR/ha), while the lowest total cost was in the year 2014 (257.386 EUR), and the lowest per hectare cost was in the year 2019 (683 EUR/ha) (Falan *et al.*, 2021).

The major marketing channels and problems faced by the silage-producing farms revealed from the KII is mentioned below.

Marketing channels of silage: sharing percentage includes of total sale volume

1. Silage firm- small-scale local cattle/buffalo/goat rearing farmers (15%)
2. Silage firm- commercial dairy cattle/buffalo/goat farm (Chitwan) (30%)
3. Silage firm-cooperatives (20 %)
4. Silage firm- commercial dairy cattle/buffalo/goat farm outside Chitwan (Kathmandu, Lalitpur, Bhaktapur, Sindhuli, Myagdi, Mustang) (35%)

Problems faced by the silage-producing firms regarding production and marketing

1. Inadequate storage facilities (damage by rats)
2. High cost of transportation
3. Unorganized marketing channel and inadequate market information
4. Supply of less quality raw materials (dried maize mixed in the green maize heap by the farmers)
5. Difficult to get subsidized agricultural loans

Supply chain Mapping of Silage

The supply chain map of the silage is prepared by identifying the actors, enablers and functions in the backward and forward linkages which are shown in the Figure 1.

Actors

The agro vets, private seed companies and other input suppliers are the actors associated with the fodder maize growing farmers in the backward linkages. The collectors, cooperatives, silage-producing firms, small and large-scale dairy cattle firms, and cooperatives are the actors of the forward linkages.

Enablers

The cooperatives maintain its role in the supply chain basically contributing to fodder maize and silage marketing, Agriculture Knowledge Centre (AKC), Nepal Agricultural Research Council (NARC), Veterinary Hospital and Livestock Service Expert Centre (VHLSEC) contribute to the production and marketing of fodder maize and silage by providing the advisory services and expert consultation to the farmers and the silage producing farms.

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Functions

The major functions as shown in the supply chain map are input supply to the farmers by the agro vets and other input supplier companies, fodder maize production by the farmers, availability of the fodder maize as raw material for silage producing firms, production of silage at silage firms and distribution of the silage to the cooperatives, large scale and small scale dairy cattle farms. The map is shown in Figure 1.

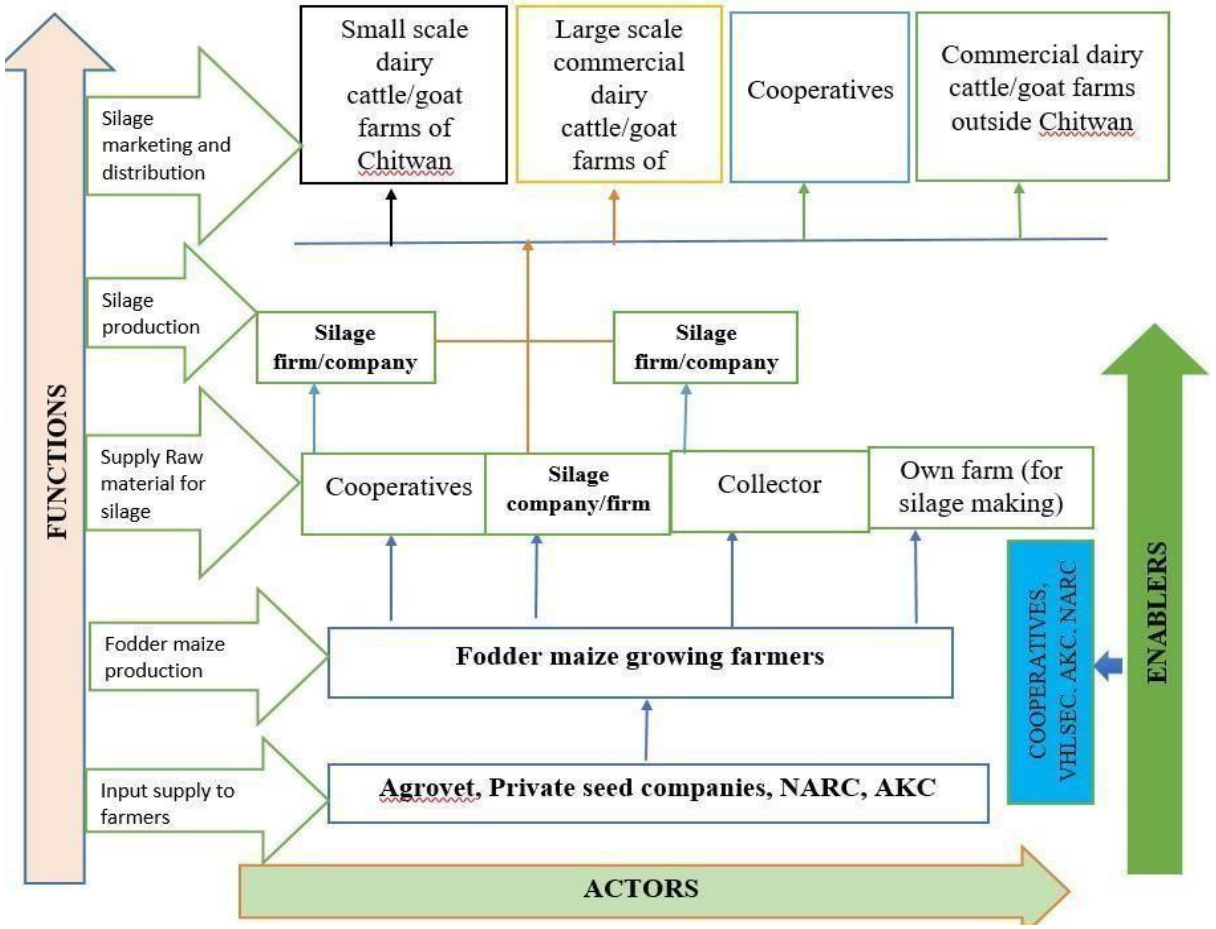

Figure 1: Supply chain map of silage revealed from the study area

Problems associated with fodder maize production

Indexing/scaling technique was applied to rank the major problems associated with fodder maize production which were identified from the FGD. Inadequate availability of fertilizers in time (I=0.85) was identified as the first major problem followed by Pest infestation (I=0.79), Inadequate availability of quality seed (I=0.65), Land fragmentation (I= 0.38) and Inadequate irrigation facilities (I=0.35) (Table 3).

A study conducted in Madichaur, Rolpa, found that the primary challenges in maize cultivation were insects, pests and pathogens. According to a study conducted in Okhaldhunga, Nepal, unavailability of labour during peak season was found to be the major problem faced by maize growers in the studied area (Dulal *et al.*, 2020). In Gujarat, India, inferior quality of seeds of fodder crops, and inadequate technical knowledge were the major problems associated with

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fodder crop production. Moreover, In Karnataka, inadequate access to credit, labour availability, and quality seed was reported as the major problems (Grover & Kumar, 2012).

Table 3: Assessment of the problems associated with fodder maize production

S. N.	Problems	Index value	Rank
1	Inadequate availability of fertilizers in time	0.85	I
2	Pest infestation	0.79	II
3	Inadequate availability of quality seed	0.65	III
4	Land fragmentation	0.38	IV
5	Inadequate irrigation facilities	0.33	V

Source: Field survey, 2023

Problems associated with fodder maize marketing

Indexing/scaling technique was again used to rank the major problems associated with the fodder maize marketing which were identified from the FGD among the farmers. Low price of the fodder maize in the market (I=0.83) was identified as the first major problem followed by an Unorganized marketing channel and inadequate coordination between the market actors (I=0.71), Inadequate market information regarding demand and supply (I=0.62), Inadequate transportation facilities (I= 0.55) and Inadequate storage facilities (I=0.32) (Table 4). Unavailability of market information on time and inadequate transport facilities at a reasonable rate were the major problems in the marketing of fodder crops revealed in Gujrat, India. Moreover, in Punjab, low prices in the market, less remuneration, lack of market information and delayed payment for the produce by the commission agents in the market were reported as the major marketing problems (Grover & Kumar, 2012). Also, A study carried out among maize farmers in Udayapur, Nepal identified several marketing-related challenges for maize, where low seasonal prices were ranked as the most serious issue, which was followed by low production volume, lack of marketing knowledge, inadequate processing facilities, and limited financing options respectively (Dahal *et al.*, 2024).

Table 4: Assessment of the problems associated with fodder maize marketing

S. N.	Problems	Index value	Rank
1.	Low price of the fodder maize in the market	0.83	I
2.	Unorganized marketing channel and inadequate coordination between the market actors	0.71	II
3.	Inadequate market information regarding demand and supply	0.62	III
4	Inadequate transportation facilities	0.55	IV
5	Inadequate storage facilities	0.32	V

Source: Field survey, 2023

CONCLUSION

The positive gross margin and BCR greater than one showed that the fodder maize production is profitable and financially viable enterprise. The positive intervention of the concerned authority such as supply of quality inputs on time and access to marketing facilities are needed in the production and marketing aspects of fodder maize. Assuring the timely availability of fertilizers, quality seed, irrigation, and price favor for the farmers, prioritizing the development of marketing channels, assuring the availability of market information, and developing the transportation and storage facilities seemed to be primary areas of intervention to promote and

strengthen the supply chain of silage. The role of cooperatives seemed to be important in the backward and forward linkages of silage as cooperatives were found to be closely associated with the marketing of fodder maize (raw material) and silage (processed product) as well. The agricultural research organizations such as NARC should put their efforts in developing the varieties of maize with high-quality attributes for silage making, and this will ultimately contribute to smoothening the supply chain of silage. Assessing the demand for silage and comparing the point of intervention to create value in existing channels for suggesting a more sustainable value chain of silage could be an important area for further research.

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Authors' Contribution

S. Subedi and K.P. Timsina designed the research plan. S.Subedi collected the data from the field survey. Moreover, S.Subedi analyzed the data and prepared the manuscript. S.Sapkota K.P. Timsina and J. Chhetri provided comments and suggestions to finalize this manuscript. The final form of the manuscript was approved by all authors.

Conflict of Interest

The authors declare that there is no conflict of interest with the present publication.

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