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# EVALUATING CARBON FOOTPRINT EMISSIONS AND CONSTRAINTS IN THE MILK VALUE CHAIN: A CASE STUDY OF DISTRICT FAISALABAD, PAKISTAN

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**Abstract**

*The development of rural areas and the economy are significantly aided by livestock. The transportation sector is one of the major contributors to the greenhouse gas emissions, resulting in climate change in Pakistan. To the contrary, milk suppliers frequently use monopolistic tactics to take advantage of customers by charging exorbitant rates, providing subpar goods, and making huge profit margins. This study intends to evaluate the carbon footprint emissions among the milk suppliers and also pinpoint the main obstacles that participants in the milk value chain in District Faisalabad confront. Data was gathered from 140 milk suppliers using a stratified simple random sampling method through well-structured questionnaire. The suppliers were categorized into small and larger, having supply up to 150 liters and more than 150 liters, respectively. Life cycle assessment (LCA) was used to calculate the $CO_2$ emissions by utilizing the 2.30 kg/liter and 2.70 kg/liter emission factor for petrol and diesel consumption, respectively. While, 0.91kg/liter emission factor for per KWhs electricity consumption. The principle component analysis (PCA) was employed to reduce the dimensions of major obstacles faced by the milk suppliers. Results indicated that the small suppliers were significantly contributing to greater Kg $CO_2$ eq./liter milk as compared to large milk suppliers, might be high fuel and energy consumption, low loading capacity and low milk supply. Moreover, technological, infrastructural, marketing, price volatility, managerial and market structures were the 6 main components of constraints faced by the milk supplier in the study area. Firstly, promoting sustainable transportation practices, such as adopting energy-efficient vehicles and optimizing delivery routes, is essential for both large and small milk suppliers. Secondly, investing in technological advancements can help overcome constraints and reduce emissions along the milk supply chain. Research and development efforts should focus on enhancing cold storage, processing, and transportation technologies to minimize energy consumption.*

## 1. INTRODUCTION

The world has developed a stronger awareness of environmental sustainability during the last few decades because people now recognize how human activities harm the planet. The world currently faces its most urgent problem through climate change because greenhouse gases have been released into the atmosphere in excessive amounts (Avotra and Nawaz, 2023; Bashir et al., 2023). Human activities produce carbon dioxide (CO2) emissions, which serve as the primary

greenhouse gas that drives global warming according to scientific research (Raihan et al., 2023; Hassan et al., 2023). A person's or organization's or product's or process's total greenhouse gas emissions which mainly consist of carbon dioxide (CO2) emissions are known as their "carbon footprint" (Aytac et al., 2023).

The world experienced a 5.3% reduction in fossil CO2 emissions during 2020 because of the COVID-19 pandemic which affected all countries. The global emissions in 2021 almost matched 2019 levels because emissions reached 37.9 gigatons (Gt) of CO2 which represented a 0.36% drop from pre-pandemic levels (Liu et al., 2023). The recovery of carbon emissions to pre-pandemic levels shows that the world has returned to its emission patterns which existed before the 2020 pandemic-induced reduction. Pakistan contributes between 0.9% and 1% to global CO2 emissions while its economy experiences greater climate change vulnerabilities (Tawiah et al., 2023). The milk value chain which plays a vital role in Pakistan's agricultural economy generates additional carbon emissions. The dairy sector faces severe pressure because increasing population numbers lead to higher milk and milk product demands. The situation has led to increased carbon emissions.

The dairy supply chain in Pakistan functions as an essential economic resource because it drives rural development while providing work opportunities to millions and delivering essential food products to meet the needs of the growing population (GOP, 2022). The supply chain's various operational stages make a substantial contribution to the carbon emissions which this critical industry generates. The processes of milk processing and milk transportation from farms to processing plants and the distribution of dairy products to customers generate both energy consumption and greenhouse gas emissions (Husnain et al., 2023; Torquati et al., 2015). The carbon footprint of these operations depends on multiple factors which include the selection of transportation methods and the energy consumed during the processing stage (Habib et al., 2018; Shamsuddoha et al., 2023).

The milk marketing system in Pakistan includes both formal and traditional elements. The traditional system doesn't require any licenses from government authorities (Sarica et al., 2022; Hameed et al., 2023). The system depends on traditional milk collectors known as Doodhis who function as middlemen between milk farmers and their customers (Brar et al., 2018; Afzal et al., 2023). Collectors purchase milk directly from dairy farms and distribute it to various marketing entities which include wholesalers retailers and customers. The system uses a number of connected market intermediaries (Zia, 2007).

The official milk marketing system requires collectors and processors and distributors to obtain government-issued licenses. The system enables different marketing organizations to collect milk from producers and convert it into various products (Yogendra and Gajendra 2017 and Ali et al. 2019). The dairy products are distributed to urban customers through the supply networks of wholesalers and retailers and distributors. The formal system ensures that licensed entities handle milk processing and collection and distribution while the traditional system allows Doodhis to sell directly to consumers. The system includes multiple marketing channels which enable different participants to fulfill distinct or interconnected functions.

The transportation of milk results in carbon emissions because vehicles burn fossil fuels during their operation. The study shows that emissions release three types of pollutants which include carbon dioxide (CO2) and nitrogen oxides (NOx) and particulate matter (PM) (Torquati et al., 2015). The number of emissions depends on various factors, such as the distance traveled, the mode of transportation, the type of vehicle, and the condition of the roads. Rural areas depend on traditional milk transportation methods which require only human power for their operations (Linton et al., 2015). The employment of traditional methods requires workers to perform their duties which results in carbon emissions that stem from their operational activities. Urban and peri-urban

regions depend on modern transportation systems which use refrigerated trucks and tankers that operate with diesel and petrol for their transportation needs, thus generating substantial carbon emissions. The country faces two main barriers which prevent it from adopting eco-friendly transportation technologies that include electric vehicles and alternative fuel vehicles (Raza et al., 2020). The geographical dispersion of milk-producing farms in rural areas necessitates longer transportation distances to reach processing facilities or urban markets, leading to increased fuel consumption and emissions (Mir et al., 2017). The emissions from milk transportation create climate change impacts which Pakistan needs to address through mitigation efforts to protect its climate resilience against extreme weather and rising temperatures. The dairy industry in Pakistan faces multiple challenges which prevent its value chain from achieving effective and profitable operations. The dairy stakeholders face major hindrances because they have to deal with five different problems which include technological limitations and insufficient infrastructure and marketing restrictions and price fluctuations and managerial challenges according to the research conducted by Ishaq and his colleagues and Islam and his colleagues in 2016 and 2018. The sector development faces obstacles because farmers take too long to adopt advanced technologies and contemporary agricultural methods. The infrastructure problems include insufficient veterinary services and inadequate storage facilities and unstable transportation networks according to research from Ishaq and his colleagues and Jalil and his colleagues in 2009. The marketability and profitability of dairy products suffer from market intelligence deficiencies and restricted access to official marketing channels. Price fluctuations together with managerial deficiencies create additional challenges for value chain operators according to the findings of Jamali and his team in 2016. The organization needs to invest in technical innovations while it develops its infrastructure and improves market access through better information sharing and training programs that will develop managerial skills. The dairy industry in Pakistan can achieve its goals through these areas which will enhance productivity and competitiveness and profitability to benefit all value chain stakeholders according to studies by Kurwijila in 2002 and Abedullah and his colleagues in 2015.

Among the range of industries that contribute, agriculture plays a large part in GHG emissions, making up around 15 to 25% of all anthropogenic GHGs, with dairy products alone making up about 5% of this proportion (GOP, 2022). Pakistan, with an agricultural economy, sees approximately 38% of its total population deriving their livelihoods either directly or indirectly from farming (GOP, 2022, Riaz et al., 2023). This dependency on agriculture makes the country particularly vulnerable to the impacts of climate change, owing to its geographical location in the region. Consequently, Pakistan has experienced the adverse effects of climate change, with floods affecting more than 33 million people (GOP, 2022). As a result, millions have lost their homes and means of earning, primarily linked to agriculture, leaving them in a state of emergency, seeking shelter and support. There is a need to quantify the carbon footprint emissions of milk supply and to identify the restrictions within the dairy supply chain. The overabundance of chain actors frequently causes systemic disruption, excessive price inflation, and issues for both producers and consumers.

## 2. Materials and Methods

### 2.1. Study Area

Although provincial-level research would have been ideal, this study was undertaken in the urban areas of the Faisalabad district due to time and resource constraints. With a population of roughly 7.87 million, Faisalabad ranks third in terms of population in Pakistan after Lahore and Karachi (GOP, 2017; Riaz and Ashfaq, 2019). Faisalabad is the second-most populated city in eastern Punjab.The city of Faisalabad is Punjab's fourth-largest milk producer, and a sizable portion of farmers there largely rely on livestock and dairy animals. Major crops like wheat, sugarcane, cotton, and maize are grown in the city, which is referred to as a mixed cropping

zone (Khalid et al., 2022). To suit the needs of the animals for feeding, several kinds of fodder are also farmed. Five tehsils make up the district of Faisalabad: Faisalabad, Samundri, Jaranwala, Tandlianwala, and Jhumra. The Nili-Ravi buffalo, Beetal goat, Lohi sheep, and Desi cattle are the most common livestock species in the region. The farming community in Faisalabad is in charge of raising over 0.534 million cows, 1 million buffalos, 0.087 million sheep, and 0.528 million goats, according to the Punjab livestock census (GOP, 2019).

Despite the specific focus on urban areas within Faisalabad district, the characteristics of the city and its prominence in milk production within Punjab make it an appropriate location for conducting this study.

2.1.2. Sample Size and Sampling Procedure

A sample is a more limited depiction of the total population because it is frequently impractical to examine the entire population due to time, financial, and physical constraints. In order to make the study more affordable and practical, a sample was chosen.

Faisalabad was separated into four strata based on geographic regions in order to assure a representative sample: (1) Canal road to Jaranwala road, (2) Jaranwala road to Sumandri road, (3) Sumandri road to Jhang road, and (4) Jhang road to Sargodha road as shown in Figure 1. To ensure diversity in the sample, a certain number of respondents were chosen from each strata. A total of 140 respondents were being interviewed by using well-structured questionnaire.

By employing a multi-stage sampling technique, the researchers aimed to obtain a comprehensive understanding of the various actors in the milk value chain and capture the perspectives of both retailers, traditional milk collectors, consumers, and those who fulfilled both roles.

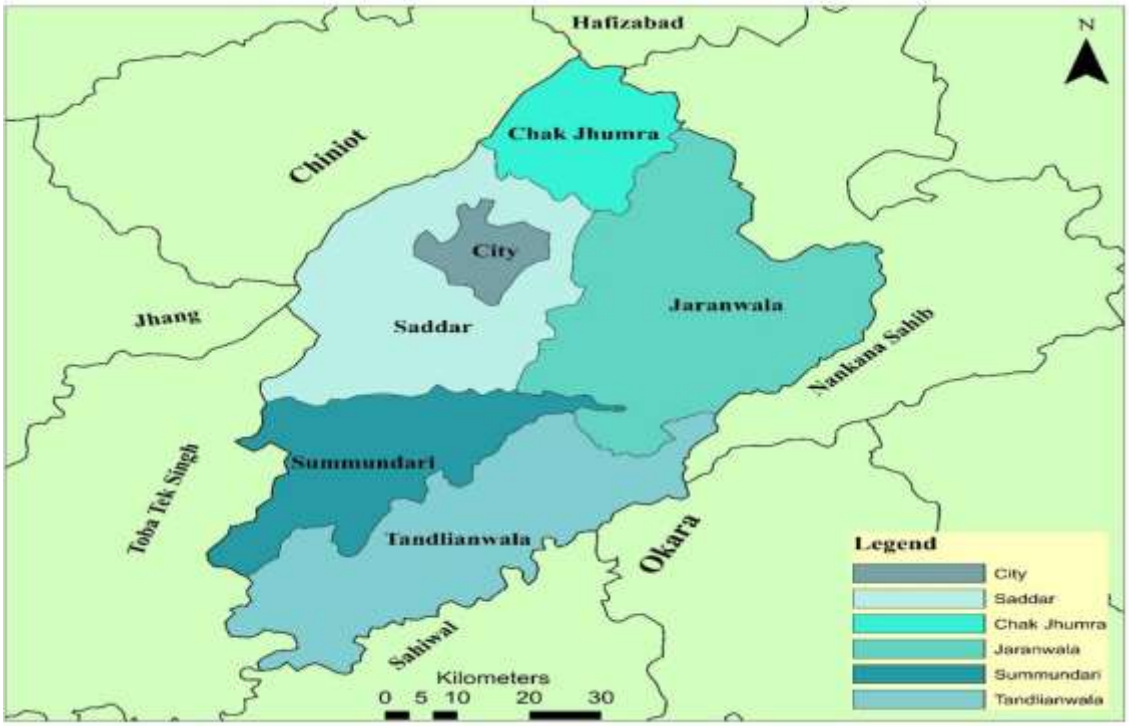



**Figure 1: Map of study area (Faisalabad) (GOP, 2023)**

**2.2. Analytical Analysis**

Milk suppliers were categorized into 2 groups based on the quantity of milk supply per day. Those suppliers who were suppling milk up to 150 liter per day categorized as small suppliers and those who were suppling milk more than 150

liter per day categorized as large suppliers. An independent t-test was employed to compare the mean $CO_2$ eq/liter milk between the small and large suppliers.

**2.2.1. Carbon footprint emission analysis**

The term "lifecycle analysis," also known as "life cycle assessment" (LCA), refers to a methodical process used to assess the environmental effects of a process, product, or service over the course of its entire life cycle, which includes stages like raw material extraction, manufacturing, distribution, use, and disposal/recycling. Its main goal is to evaluate each stage's impact on the environment, including resource use, energy use, emissions into the air, water, and soil, and waste production (Zhang et al., 2021). Decision-makers can make well-informed decisions targeted at minimizing the total environmental effect by analyzing these consequences and identifying the major areas with high environmental burden (Wang and Sun, 2012). This thorough technique was used to assess the carbon footprint emissions generated throughout the handling and delivery of milk from farmers to retailers and end users.

**2.2.1.1. $CO_2$ emissions calculation**

Transport, storage, and processing processes are the main sources of CO2 emissions in the milk production and distribution process. Additionally, selling milk and its different derivatives to final customers has a considerable impact on emissions (Torquati et al., 2015).

Equation 1 is used in the computation to calculate the emissions from transportation (Misganaw et al., 2021). This equation takes into account two key variables: the daily distance travelled by milk suppliers for milk delivery and the quantity of fuel and diesel used by the vehicles. For delivering milk to final customers, specific emission factors for petrol and diesel are used, with values of 2.30 kg/liter and 2.70 kg/liter, respectively. The total CO2 equivalent emissions are divided by the total amount of milk delivered to get the per-liter CO2 emission.

$$CO_2\ Vehicle\ Emissions = Distance\ traveled\ (km) * fuel\ consumption(liters) * emission\ factor \quad (1)$$

Similarly, the emissions resulting from the storage and processing of milk are determined using Equation 2 (Misganaw et al., 2021). This equation incorporates the KWhs (kilowatt-hours) of electricity energy used for storing and processing the milk, with an emission factor of 0.91 kg/liter calculated by the Faisalabad Electric Supply Company (FESCO). To calculate the per liter CO2 emission, the total CO2 equivalent emissions are divided by the total amount of milk stored or processed.

$$CO_2\ \ Stoarge\ Emissions = \sum_{i=n}^{n} E_i KWhs * emission\ factor \quad (2)$$

**2.2.2. Constraints Analysis**

The principle component analysis (PCA) was used for constraints analysis for the milk suppliers and consumers of dairy. The detail of principle component analysis is given as under;

**2.2.1. Principle Component Analysis**

In order to minimise the dimensionality of the dataset and find the important components or factors that account for the variance in the variables, the analytical framework used in this research study combines principal component analysis (PCA) and factor analysis.

A dataset with many associated variables is transformed into a new collection of variables known as principal components using the statistical method of principal component analysis (PCA) (Agilan et al., 2023; Zhan et al., 2023). The main goal of PCA is to decrease the dataset's dimensionality while maintaining as much variance as possible in the original variables. The principle components are arranged so that the first component represents the highest level of variation present in the original variables, while succeeding components capture progressively lower levels of variance. The eigenvectors of a covariance matrix that make up the principal components are symmetrical (Ahsan, 2011).

Factor analysis was employed to further reduce the number of variables to a set of principal components. The selection of key components

was determined based on the criterion of eigenvalue ≥ 1 (Liu et al., 2023, Akhtar et al., 2023). The sources of risks and techniques were categorized into different variables using a rotated component matrix or a symmetrical varimax rotation table (Meuwissan et al., 2001; Bergfjord, 2009).

Bartlett's test and the Kaiser-Meyer-Olkin (KMO) metric were used to evaluate the effectiveness of the factor analysis. The KMO metric evaluates the relationship coefficients to determine whether factor analysis is appropriate. For factor analysis, a KMO value greater than 0.5 is regarded as appropriate (Akhtar et al., 2023). The idea that all components in the population are uncorrelated is tested using Bartlett's test (Aurum et al., 2008).

The 22 and 17 limitations, respectively, were derived from the initial set of restrictions for intermediaries and consumers that were found in the literature. These limitations applied to milk quality, marketing, handling, and availability, price, handling of adulterated milk, health concerns, and other pertinent variables. On a 5-point Likert scale, from strongly disagree to strongly agree, the respondents were asked to score these restrictions. A detailed econometric methodological discussion can be found in Akbar et al. (2025).

## 3. Results and Discussion

### 3.1. Socio-economic characteristics of milk suppliers

Socio-economic characteristics hold significant importance in the lives of individuals, whether they are entrepreneurs or daily laborers within society. It also play a pivotal role in distinguishing individuals within society into higher or lower classes (Khalid et al., 2022). The results reveal significant differences between small and larger milk suppliers in terms of the average number of family members, earners, income level, number of hired labor, and experience as a milk supplier (Table 1). The larger suppliers have more than double income level and number of hired labor and about 3 years more experience as compare to the smaller counterparts. In case of family dynamics, it was evident that the small milk supplier has smaller average family size, less number of earners, low income level, hiring less labor and low experience as compared to larger counterparts. The small milk suppliers have less resources in hand but greater attention and responsibilities to manage the entrepreneurial activities. Moreover, they have less experience in business that ultimately might be an obstacle to compete the competitors (large suppliers) in the market.

**Table 1: Socio-economic Characteristics of milk supplier**

| Variable | Small Supplier (N=70) | Large Supplier (N=70) | T-Value | P-value |
|---|---|---|---|---|
| Age (years) | 36.44 (11.91) | 35.69 (11.93) | 0.376 | 0.708 |
| Education (years) | 5.39 (3.65) | 5.54 (4.73) | -0.220 | 0.826 |
| Family members (no.) | 6.30 (3.85) | 8.10 (4.61) | -2.504 | 0.013 |
| No. of earners | 1.53 (0.94) | 2.29 (1.57) | -3.457 | 0.001 |
| Income (PKR/month) | 39500 (21855.08) | 97214.29 (16430.79) | -2.860 | 0.005 |
| Hired labor (no.) | 0.14 (0.427) | 0.53 (1.45) | -2.133 | 0.035 |
| Experience (years) | 8.90 (7.76) | 11.90 (8.84) | -2.132 | 0.035 |

### 3.2. Milk collection sources

The small and large milk suppliers differed not only in terms of socio-economic characteristics but also in their sources of milk collection. The findings revealed three main sources of milk collection: own farm, farmers, and other suppliers. Approximately 47% of small milk suppliers collected milk from their own farms, while 53% sourced milk from farmers and other suppliers. While, approximately 54% of large milk suppliers were collecting milk from farmers and 46% from their own farms and other suppliers in the study area (Table 2).

**Table 2: Source of milk collection**

| Source of milk collection | | Small Suppliers | Large Suppliers |
|---|---|---|---|
| Own Farm | N | 33 | 23 |
| | Mean | 73.48 | 123.04 |
| | Std. Dev. | 42.43 | 65.86 |
| Farmers | N | 26 | 38 |
| | Mean | 88.81 | 213.82 |
| | Std. Dev. | 17.99 | 97.47 |
| Suppliers | N | 74.29 | 21 |
| | Mean | 21 | 74.29 |
| | Std. Dev. | 28.90 | 28.91 |
| Total | N | 70 | 70 |
| | Mean | 89.91 | 226.07 |
| | Std. Dev. | 30.01 | 68.08 |

### 3.3. Comparative analysis of carbon footprint emissions

The carbon footprint emissions resulting from milk transportation by milk suppliers are influenced primarily by three factors: vehicle types, distance covered, and fuel consumption. Additionally, electricity consumption for milk storage and processing also plays a significant role in carbon footprint emissions.

The study revealed that among the small milk suppliers, 60% utilized CD-70 bikes, which are considered an economical transportation source, while the remaining 40% used Yamaha bikes, Rickshaws, and Carry dabas. In contrast, approximately 73% of the large milk suppliers employed carry dabas, and the remaining 27% utilized Yamaha bikes and Rickshaws for milk transportation within the study area.

Ownership status of the vehicles varied between small and large suppliers, with a majority of small suppliers owning their vehicles compared to large suppliers. Regarding the daily distances covered, large milk suppliers covered approximately 67 kilometers, consuming 8.59 liters of fuel, while small milk suppliers traveled about 42 kilometers, with a fuel consumption of 5.06 liters. In terms of electricity consumption, the study found that larger suppliers consumed more electricity compared to their smaller counterparts (Table 3). The large suppliers were found to be greater fuel and electricity consumers, might be due to greater handling and transportation operations of bulk quantity milk.

**Table 3: Vehicle types, ownership and storage particulars of milk suppliers**

| Variable | Small Supplier (N=70) | Large Supplier (N=70) |
|---|---|---|
| Vehicle Type (%) | | |
| CD-70 Bike | 60.00 | - |
| Yamaha Bike | 21.43 | 04.28 |
| Rickshaw | 04.29 | 22.86 |
| Carry Daba | 14.28 | 72.86 |
| Vehicle Ownership (%) | | |
| Yes | 91.43 | 68.57 |
| No | 08.57 | 31.42 |
| Average Rent (PKR/day) | 1316.67 (194.08) | 1904.55 (374.77) |
| Average Distance Travel (Km/day) | 42.09 (7.47) | 67.20 (8.87) |
| Average Fuel Consumption (Liter/day) | 5.06 (2.07) | 8.59 (3.01) |
| Have a storage facility? (%) | | |

| | | |
|---|---|---|
| Yes | 87.14 | 90.00 |
| No | 12.86 | 10.00 |
| Average electricity consumption (KWh/day) | 5.53 (0.92) | 8.22 (1.13) |

In the milk value chain, two primary sources contribute to carbon footprint emissions: transportation and storage. Milk suppliers are responsible for transporting milk from production to retail and consumer ends. Within the study area, it was observed that large suppliers transport, handle, and process milk in bulk quantities, covering larger distances with the use of big transporting vehicles.

The study's findings revealed that the total carbon footprint emissions (measured in Kgs) from transporting milk by both large and small suppliers were not significantly different. However, the carbon footprint (measured in Kgs) per liter of milk transported showed a significant difference between the small and large suppliers. This difference can likely be attributed to the larger distances covered and the utilization of bigger milk transportation methods by the larger suppliers.

A comparative analysis of electricity consumption for milk handling and processing showed a significant difference between the suppliers. Additionally, the carbon footprint emissions (measured in Kgs) resulting from storage and processing operations were also found to be significantly different among the suppliers. When considering the overall carbon footprint emissions (Kgs) associated with transporting and handling per liter of milk, there was a significant difference between the small and large suppliers (Table 4).

These findings indicate that the size of the supplier and their respective transportation and storage methods play a crucial role in determining the carbon footprint impact within the milk value chain. The smaller suppliers of milk producing high carbon footprint emissions (Kgs) might because of covering long distances with small vehicle turns and carrying low quantity of milk. Misganaw et al., (2021) also found the same results where small suppliers were contributing significantly greater than the larger suppliers.

**Table 4: Comparative carbon footprint emissions among the milk suppliers**

| Variable | Small Supplier (N=70) | Large Supplier (N=70) | T-value | p-value |
|---|---|---|---|---|
| Distance covered (Km) | 42.09 (7.47) | 67.20 (8.87) | -18.11 | 0.000 |
| Distributed milk (liters) | 89.91 (30.00) | 226.07 (68.08) | -15.31 | 0.000 |
| Fuel Consumption | 2.68 (1.61) | 2.67 (1.74) | 0.023 | 0.982 |
| Carbon Footprint produced from vehicle usage | 6.17 (3.71) | 6.16 (4.01) | 0.023 | 0.982 |
| Carbon footprint per liter milk transported | 0.042 (0.026) | 0.032 (0.029) | 1.95 | 0.052 |
| Electricity consumed (KWh) | 5.52 (0.92) | 8.22 (1.13) | -15.43 | 0.000 |
| Carbon Footprint produced from electricity usage | 2.24 (0.75) | 2.36 (0.85) | -0.87 | 0.383 |
| Carbon footprint per liter milk stored | 0.015 (0.006) | 0.011 (0.006) | 3.22 | 0.002 |
| Total CF per liter milk | 0.056 (0.02) | 0.044 (0.03) | 2.44 | 0.016 |

### 3.4. Constraints analysis faced by the milk suppliers

High environmental pressures came in first as a limitation for intermediaries (mean value: 4.173), indicating severe difficulties relating to environmental concerns. The second most problematic factor is price changes (mean value: 4.014), which are problematic since milk costs

might fluctuate suddenly. The third-ranked factors (mean value: 3.900) are inadequate road systems and transportation costs, which pose difficulties for efficient transportation. The fourth limitation, a lack of capital (mean value: 3.857), prevents financial resources from being used for investment and expansion. The sixth factor, inconsistent information (mean value 3.850), reflects difficulties in obtaining trustworthy market data (Table 5). These results highlight the need for interventions and enhancements to deal with these limitations and increase the efficiency of milk suppliers in the dairy business.

**Table 5: Mean Rank Score of constraints faced by the milk distributors**

| Constraints | Mean | Score Ranks | Std. Deviation |
|---|---|---|---|
| High environmental stresses | 4.157 | 1 | .9078 |
| Price fluctuations | 4.014 | 2 | .9520 |
| Poor road systems | 3.900 | 3 | .7326 |
| High cost of transportation | 3.857 | 4 | .7826 |
| Lack of Capital | 3.850 | 5 | 1.1119 |
| Lack of up-to-date and consistent information | 3.850 | 6 | 1.0589 |
| Spoilage of milk | 3.843 | 7 | .8589 |
| High ambient temperature of the area | 3.800 | 8 | 1.1329 |
| Long distance between collection point and markets | 3.800 | 9 | .9151 |
| Low shelf-life of milk | 3.800 | 10 | 1.1201 |
| High energy costs | 3.779 | 11 | .9676 |
| Unreliable market | 3.614 | 12 | 1.3967 |
| Lack of processing technology | 3.593 | 13 | 1.1623 |
| Inadequate policies | 3.586 | 14 | 1.0318 |
| Poor regulation of milk | 3.543 | 15 | 1.1897 |
| Lack of drinking milk habits | 3.414 | 16 | 1.3357 |
| Sale of un-pasteurized milk | 3.393 | 17 | 1.3608 |
| Poor handling of milk | 3.371 | 18 | 1.1274 |

| | | | |
|---|---|---|---|
| Lack of milk storage and cooling facilities | 3.286 | 19 | 1.2308 |
| Insufficient raw milk supply | 3.207 | 20 | 1.4116 |
| Sales Tax | 3.050 | 21 | 1.1650 |
| Low education level | 2.943 | 22 | 1.6305 |

KMO and Bartlett's tests were used to evaluate the adequacy of factor analysis and the correlation between variables in the context of this scientific paper's results and discussion section. By comparing the magnitude of all observed correlation coefficients with the size of the partial correlation coefficients, the KMO test evaluates the sample's suitability for factor analysis. Given that it is more than the cutoff value of 0.50 in this study, the estimated KMO statistic of 0.787 suggests that the sample is appropriate for factor analysis. This information is shown in table 6, which supports the appropriateness of using factor analysis to examine the limitations faced by milk suppliers.
The Sphericity test used by the Bartlett also examines the uni-correlation of all observable variables in the entire population. The Chi-Square value of the test is 1837.15 implying that the null hypothesis is rejected. This rejection indicates the interconnectedness of the limitations experienced by intermediaries by indicating that there is statistically significant correlation of the observed variables. The resultant effect is the emphasis on the significance of considering such correlations when analyzing the rest of the results of the factor analysis. These tests contribute to the assurance that the restrictions that are identified are representative and provide valuable information about the challenges faced by milk suppliers. They also help towards the strength and reliability of the study.

**Table 6: KMO and Bartlett's Test for constraints faced by the milk suppliers**

| KMO and Bartlett's Test | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .787 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 1837.155 |
| | Df | 231 |
| | Sig. | .000 |

After ensuring that the data was adequate to conduct a factor analysis, the 22 variables that represented the critical success factors/barriers of KM were then subjected to a principal component analysis in order to ascertain the overall amount of variance that these constraints explained. Factor extraction was done on the Latent root criterion (eigenvalue criterion) and the Scree plot.
Factors whose eigenvalues were more than 1.0 were used in further analysis. Out of these elements, there were six factors with eigenvalues more than one. The initial factor explained 35.5 percent of the variation and this shows that it explains a significant part of the variability in the constraints that milk suppliers face. The second and the third factors contributed 10.8 and 7.79 percent of the variance respectively, which significantly added to the comprehension of the underlying constraints. The 6th, 5th and 4th components respectively contributed 4.9, 5.59 and 6.02% of the variance. The other factors had eigenvalues lower than 1.0 implying that they had lower impacts on the total variance. These remaining components did not thus explain the variance of more than 4.90 (Table 7).

These findings provide useful data regarding the relative importance and value of each factor to explain the overall variance observed in the constraints experienced by milk suppliers. The scree plot, which is a graph of the components on the X-axis and the initial eigenvalues on the Y-axis, reveals the magnitude of the initial eigenvalues, and the share of the overall variance that the component captures. The first six eigenvalues are equal or higher than unity as observed in the scree plot, and the rest of the components have lesser eigenvalues than unity. This implies that the most important causes of variation of the data are contained in the top six components. The scree plot also reveals that these 6 factors explain nearly 70 percent of the total variance. This fact highlights the importance of these essential aspects of understanding the underlying trends and factors affecting the boundaries that milk suppliers go through (Figure 2).

Scree plot helps determine the best number of components to use in future study by graphically illustrating the eigenvalues thus facilitating easier analysis and drawing worth analyzing information out of the principal component analysis. According to the principal component analysis, and methods used to identify the number of factors, six factors were identified to have met the factor determination criteria. These variables are known as the Critical Success Factors/Barriers of Knowledge Management (KM) implementation in SE organizations. These aspects were obtained by the amalgamation of 22 variables that were converted to the assertive statement form and measured on a 5-point Likert scale. These Critical Success Factors/Barriers are critical dimensions that are significantly involved in the successful implementation of KM at SE organizations. The categorization and unification of the variables into these factors enable this study to make valuable contributions to the body of knowledge in this field since it establishes the factors that are critical in either promoting or inhibiting the KM implementation.

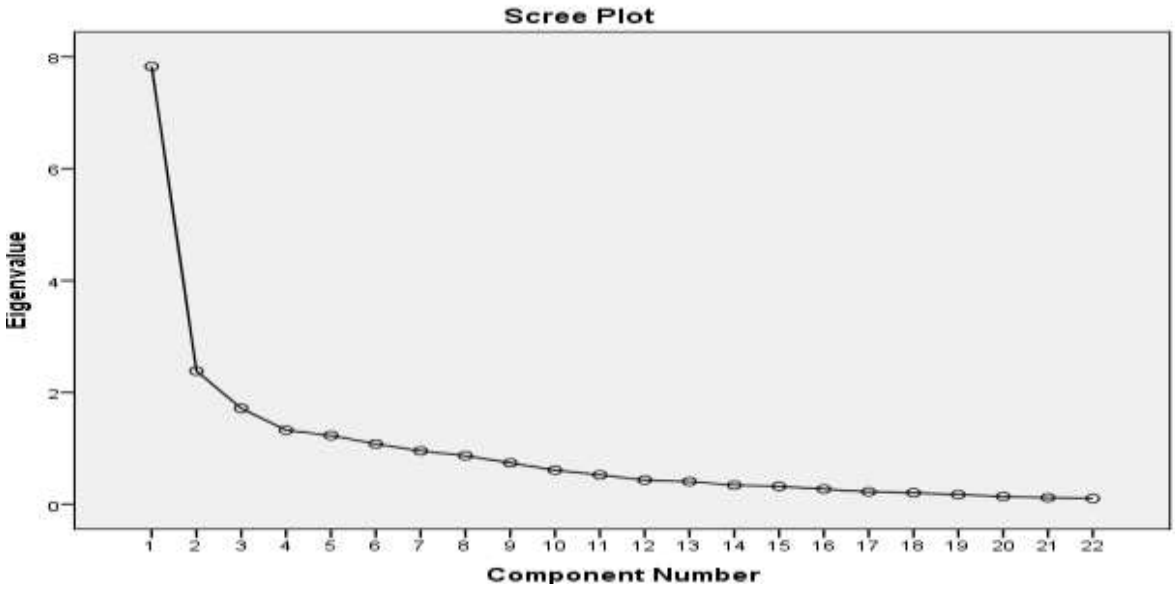



**Figure 2: Scree Plot of Components and Eigen values**

The results of the principal component analysis, identified the key success factors, and obstacles to the knowledge management (KM) adoption in the dairy industry among milk suppliers. Of the identified constraints, technological constraint proves to be the greatest challenge among the milk suppliers. It means that ineffective KM implementation is a significant challenge due to

the absence of technological innovations and access to the necessary tools and systems. The same limitations encountered by the dairy value chain participants in the process of marketing the dairy products in the local markets are also observed by Abedullah et al., (2015) and Hassan et al., (2023). Infrastructure and marketing constraints are the next two variables that follow this, indicating the relevance of sound infrastructure and effective marketing mechanisms in successful KM practices. Price volatility and managerial constraints are also identified as significant obstacles, suggesting that milk suppliers encounter difficulties in managing price fluctuations and in implementing effective managerial practices. On the other hand, market structural constraints are found to be the least important factor among the identified constraints, similar findings has been found by the Hagmann (2012). These findings shed light on the specific areas that need attention and improvement in the dairy sector to enhance KM implementation and overcome the identified barriers faced by milk suppliers.

**Table 7: Critical Success Factors and Barriers to KM Implementation**

| Sr. no | Component | Factor Loadings | Factors in component |
|---|---|---|---|
| 1 | Technological constraints | 0.490 | • Lack of Capital |
| | | 0.610 | • Inadequate policies |
| | | 0.719 | • Poor regulation of milk |
| | | 0.837 | • Poor handling of milk |
| | | 0.810 | • Lack of milk storage and storage facilities |
| | | 0.774 | • Lack of processing technology |
| | | 0.661 | • Lack of drinking milk habits |
| 2 | Infrastructure constraints | 0.638 | • High cost of transportation |
| | | 0.803 | • Poor road systems |
| | | 0.849 | • Spoilage of milk |
| 3 | Marketing constraints | 0.638 | • High education level |
| | | 0.858 | • Sales Tax |
| | | 0.597 | • Sale of un-pasteurized milk |
| | | 0.623 | • Insufficient raw milk supply |
| 4 | Price volatility constraints | 0.498 | • High energy costs |
| | | 0.808 | • Price fluctuations |
| | | 0.745 | • High environmental stresses |
| 5 | Managerial constraints | 0.696 | • Low shelf-life of milk |
| | | 0.474 | • High ambient temperature of the area |
| | | 0.547 | • Long distance between collection point and markets |
| 6 | Market structural constraints | 0.534 | • Unreliable market |
| | | 0.893 | • Lack of up-to-date and consistent information |

## 4. Conclusion

Transportation sector is the main contributor to the GHGs emissions that impacting the climate change over the globe. This study concludes that the small suppliers were contributing significantly greater to the mean kg $CO_2$ eq./liter milk emissions while using transportation and storage operations to supply the milk to end-consumers

as compared to the large suppliers. This might be due to high fuel and electricity consumption, low loading vehicles capacity, and low milk supply. Based on the findings of the study, it is also concluded that technological constraints pose the most significant obstacle for milk suppliers in the dairy sector, followed by infrastructure and marketing constraints, while price volatility and managerial challenges are also significant hurdles. Market structural constraints were found to be the least important factor. To address the significant greenhouse gas emissions from the transportation sector impacting global climate change, the dairy industry can take several impactful measures. Firstly, promoting sustainable transportation practices, such as adopting energy-efficient vehicles and optimizing delivery routes, is essential for both large and small milk suppliers. Secondly, investing in technological advancements can help overcome constraints and reduce emissions along the milk supply chain. Research and development efforts should focus on enhancing cold storage, processing, and transportation technologies to minimize energy consumption. Thirdly, strengthening infrastructure, including transportation networks and storage facilities, will facilitate more efficient milk supply routes and decrease overall emissions. Lastly, implementing green marketing initiatives and knowledge-sharing platforms can encourage consumers to make eco-conscious choices while supporting milk suppliers in adopting sustainable practices. These combined efforts can significantly reduce the dairy sector's environmental impact and contribute to global sustainability goals.

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