

Article

Analysis of Factors Influencing the Efficiency of Milk Production and Their Classification

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Abstract: This article analyzes the main factors influencing the efficiency of milk production and examines the classification of dairy cattle based on productivity levels. The study was conducted in farms and household plots of the Samarkand region, where data were collected on 616 cattle and the factors affecting their productivity. The Finite Mixture Model (FMM) was applied in the analysis, and cattle were classified into low, medium, and high productivity groups based on milk yield. The results showed that milk productivity largely depends on the quality and quantity of feed, breed characteristics, housing conditions, and the level of veterinary services. It was found that high-productivity groups are characterized by balanced rations, modern technologies, and efficient management practices. Based on the research findings, practical recommendations for improving milk production efficiency have been developed.

Keywords: Milk Production Efficiency, Dairy Cattle Productivity, Finite Mixture Model (FMM), Milk Yield, Feeding Management, Breed Characteristics, Dairy Farming, Livestock Productivity, Farm Management, Samarkand Region.

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1. Introduction

Milk and dairy products play a vital role in human nutrition, providing essential proteins, vitamins, and minerals. The growing demand for dairy products has increased the importance of improving milk production efficiency and enhancing the productivity of dairy cattle. In this context, milk yield per cow has become a key indicator of performance in the livestock sector [1].

Dairy cattle productivity is influenced by a combination of economic and biological factors, including feeding systems, breed characteristics, housing conditions, and farm management practices. Previous studies have shown that improvements in nutrition, genetics, and management significantly contribute to higher milk yields, while disparities across farms highlight existing inefficiencies and production gaps.

Modern research increasingly focuses on classifying livestock according to productivity levels in order to identify underperforming groups and develop targeted interventions. Advanced statistical approaches, such as the Finite Mixture Model (FMM), allow for more accurate analysis of heterogeneous data and provide deeper insights into productivity patterns [2].

This study aims to analyze the factors affecting milk production efficiency and to classify dairy cattle into productivity groups using FMM, based on empirical data from

the Samarkand region. The results are expected to support the development of effective strategies for improving dairy farm performance.

Literature Review.

Milk production efficiency and dairy cattle productivity have been widely examined in scientific research, with studies consistently indicating that milk yield is determined by a combination of genetic, physiological, nutritional, and environmental factors. In particular, breed characteristics, lactation period, feed quality, and housing conditions are identified as key determinants of productivity. The literature shows that productivity can be evaluated using different criteria depending on research objectives, including breed-specific indicators, lactation-based measures, and farm-level daily milk yield assessments [3].

Recent studies have increasingly focused on classifying dairy cattle according to productivity levels. For example, Sherif Moawed et al. applied discriminant analysis methods to classify cows into low, medium, and high productivity groups, while Igino Andrighetto et al. demonstrated that differences in milk yield are largely driven by feeding efficiency, diet balance, and management practices. Their findings highlight that accurate classification of productivity levels is essential for improving farm efficiency and optimizing resource use in dairy production systems [4].

2. Research Methodology

This study is based on primary data collected from household plots, large agrofirms, and *qepmep* farms in the Samarkand region. The dataset includes information on 616 dairy cattle. To avoid bias in the analysis, the sample was constructed to ensure a relatively balanced representation of both local and imported breeds. This approach improves the reliability and comparability of the results [5].

To classify dairy cattle according to productivity levels, the Finite Mixture Model (FMM) was applied. This probabilistic method allows for identifying latent (unobserved) groups within heterogeneous data. Based on the FMM results, dairy cattle were objectively classified into distinct productivity categories, providing a statistically grounded framework for evaluating milk production efficiency.

3. Results and Discussion

Milk and dairy products are essential for human nutrition due to their rich content of proteins, minerals and vitamins. For this reason, they are considered essential components of the daily diet. In recent years, the demand for dairy products has been steadily increasing, which, in turn, necessitates an increase in milk yield per dairy cow [6].

The productivity of cattle is generally understood as the volume of output obtained, including milk, meat, and other products. However, under conditions of dairy farming, primary emphasis is placed on milk productivity, as it serves as a key indicator of farm efficiency.

Following calving, a cow enters the lactation period, during which milk production occurs. During this stage, productivity initially rises rapidly, reaching its peak approximately 40–60 days after calving. Thereafter, a gradual decline in milk yield is observed, averaging about 10% per month. In addition, as the animal ages and the number of lactations increases (up to approximately the sixth lactation), its productivity tends to improve [8].

Indicators of cattle productivity can be classified in various ways depending on the objectives of the study. Scientific research identifies different types of criteria, including productivity indicators developed and analyzed for dairy cattle of a specific breed,

indicators reflecting a cow's productivity over a single lactation period, and daily productivity indicators measured under the conditions of a particular farm.

In a study conducted by Sherif Moswed and his colleagues, a productivity criterion was developed for Holstein–Friesian cows in the El-Dakahlia region (Egypt). The analytical results were obtained using linear discriminant analysis (LDA) and flexible (functional or curved) discriminant analysis (FDA) models. Based on these methods, productivity levels for Friesian cattle were classified as low (<4500 kg/year), medium (4500–7500 kg/year), and high (>7500 kg/year). These classifications can be applied in the development of various technological approaches and predictive models. The analysis demonstrated a scientifically grounded classification accuracy of approximately 82% [9].

In a study conducted by Iginio Andrighetto and his colleagues, differences in milk yield were identified and their underlying causes were analyzed across 29 large dairy farms in the northern region of Italy. The aim of the study was to determine the extent to which factors affecting feeding efficiency and milk yield in cows depend on nutrition and housing conditions.

According to the results, low-producing cows yielded 31.1 kg/day, medium-producing cows yielded 31.1–36.7 kg/day, and high-producing cows yielded more than 36.7 kg/day of milk. Statistical analysis, carried out using analysis of variance (ANOVA) and regression models, revealed the influence of various factors. It was demonstrated that cows in the highest productivity group exhibited higher dry matter intake, greater feed digestibility, and a more uniform (balanced) diet [10].

For the analysis Figure 1, data were collected on 616 head of livestock, including both local and imported breeds. The data were obtained from 316 households through questionnaires, as well as from large farms and agricultural enterprises. Sixteen questionnaires were excluded from the analysis due to missing information required for the study. Data on 616 cows and the factors affecting their productivity were collected from livestock farms and households in the Akdarya, Payariq, and Narpay districts. Due to the large population of local cattle in the region, the numbers of local and imported animals were nearly equal. A Finite Mixture Model (FMM) was employed for this analysis [11].

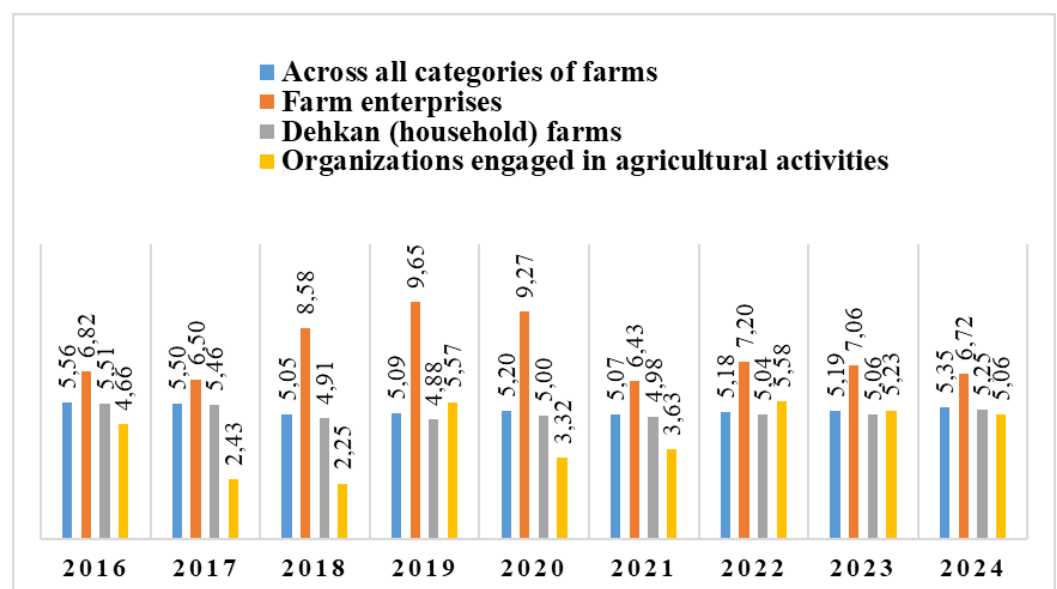


Figure 1. Analysis of the Average Daily Milk Yield per Dairy Cow across Different Categories of Farms in the Samarkand Region for the Period 2016–2024.

Figure 2. shows that the first peak of the curve is located approximately at 7–10 liters, the second peak at 25–30 liters, while the intermediate range lies around 15–20 liters. These

intervals indicate the possibility of clearly distinguishing between different levels of livestock productivity. This pattern demonstrates that the Finite Mixture Model (FMM) is well-suited for grouping the data. More precisely, the FMM objectively classifies cows into probable groups according to their productivity levels [12].

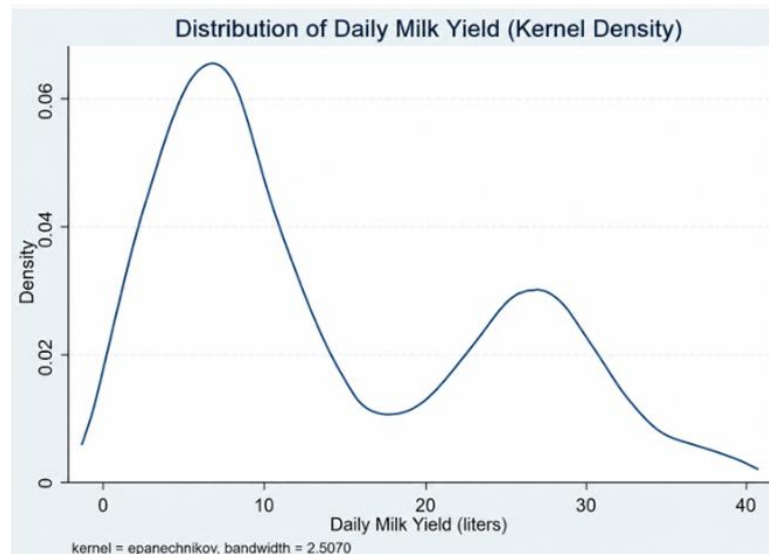


Figure 2. Visual Representation of multimodality in the distribution of daily milk yield.

Table 1. data indicate that low-productivity cows are those producing less than 6 liters of milk. At this level, feed balance and animal quality are low, housing conditions are poor, and the breeds are predominantly local. Such cattle are mainly kept on farms located near urban areas, without access to pastures or forage resources [13].

Table 1. Productivity Criteria of Dairy Cattle in the Samarkand Region.

Level of dairy cattle productivity	Control indicators	Average productivity level
Low	< 6	4.43
Medium	6-15	9.32
High	>15	25.84

Cattle in the medium category are raised under significantly better conditions, including higher-quality feed, well-organized barns and pastures, and regular veterinary supervision. These animals are mostly of improved breeds, including local, Simmental, Black-and-White, Estonian, and Holstein cattle.

High-productivity cattle mainly consist of Simmental and Holstein breeds from large livestock farms and agricultural enterprises. Their feeding systems differ fundamentally from those of household cattle: they are fed throughout the day, provided with continuous access to water (via specialized drinking systems), and even water temperature is regulated. Care and veterinary services are properly organized and regularly maintained. The feed base is strong, nutrition is based on balanced rations, and particular attention is paid to feed quality. As a result, the productivity of cattle in this category is significantly higher.

The groups classified according to the productivity criterion are presented in a visual representation created using STATA 18 (Figure 3). The graph clearly illustrates the levels of milk productivity across the groups. The first group 'represents cattle with the lowest productivity. It is advisable to implement measures to increase productivity in this group.

Improving feeding systems, introducing modern equipment and technologies, and upgrading existing infrastructure can help enhance their low productivity.

For the middle group, productivity can be improved through the application of modern management practices, innovative technologies and genetic improvements. In the top-performing group, leadership can be maintained through the continuous adoption of advanced and innovative technologies [14].

The Figure 3. low classification group includes data on 210 head of cattle, with most animals characterized by uniformly low productivity (ranging from 1 to 6 liters). The variation in milk production is minimal, resulting in a compact appearance of the diagram. This situation is explained by the low level of diversification and the homogeneity of the resources used.

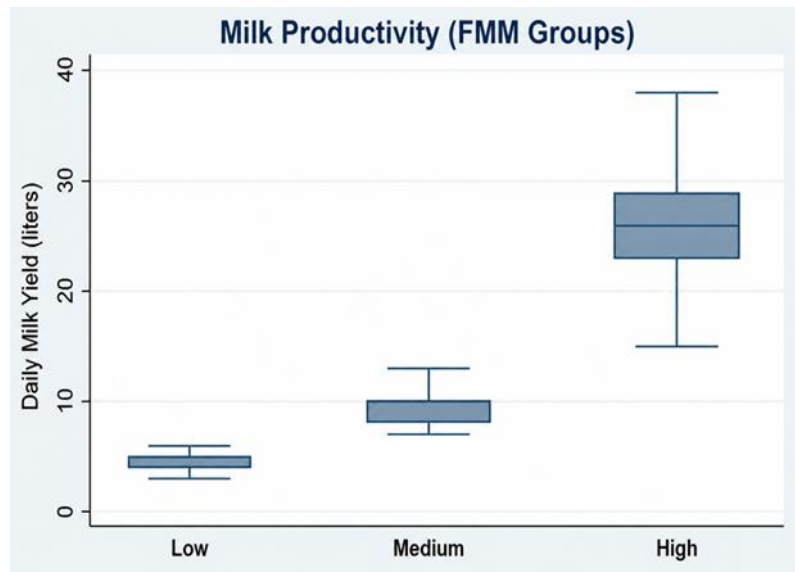


Figure 3. Boxplot Classification of Dairy Cattle Productivity.

In contrast, the medium and high groups exhibit significantly greater variation. This is due to the influence of factors such as differences in breeds, feeding methods and technologies, as well as the effectiveness of farm management practices [15].

4. Conclusions

Dairy farming at the global level is not only one of the key sectors ensuring food security, but also a strategic industry that contributes to increasing household incomes, reducing poverty, creating employment opportunities along the value chain, and enhancing the competitiveness of the national economy.

This study analyzed the main factors influencing milk production efficiency and classified dairy cattle into productivity groups using the Finite Mixture Model (FMM). The results confirmed that milk productivity is significantly affected by key factors such as feed quality and quantity, breed characteristics, housing conditions, and the level of veterinary services. In particular, feeding and management practices were identified as the most influential determinants of productivity.

The application of the FMM allowed for the identification of three distinct productivity groups—low, medium, and high—based on daily milk yield. The findings revealed substantial differences between these groups, with high-productivity cattle benefiting from balanced nutrition, improved breeds, and advanced management

practices. In contrast, low-productivity cattle were associated with poor feeding conditions and inadequate farm infrastructure.

Based on the results, it can be concluded that improving feeding systems, strengthening veterinary services, and adopting modern farm management practices are essential for increasing milk production efficiency. The study provides practical implications for farmers and policymakers, emphasizing the importance of targeted interventions to enhance productivity and ensure sustainable development of the dairy sector.

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