Journal of Autonomous Intelligence (2021) Volume 4 Issue 2.
doi: 10.32629/jai.v4i1.502

Original Research Article

Comparison and Selection of Artificial Intelligence Technology in Predicting Milk Yield

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ABSTRACT

Forecasts are an effective decision-making tool, mainly in the dairy industry, because they help improve herd management, save farm energy and optimize long-term capital investment. The application of artificial intelligence technology to predict milk yield is a subject of concern in the scientific community. However, defining a technology or model to predict the effective performance of these products in different environments is a challenging and complex activity, because none of them is accurate in all scenarios. This study compared the application of artificial intelligence technology in milk yield prediction in the literature, and applied analytic hierarchy process to select the most suitable artificial intelligence technology for milk yield prediction. Methods comprehensive analysis, investigation and experiment were used. The results show that the artificial intelligence technology based on artificial neural network is more suitable for the prediction of milk yield than decision tree and support vector machine. In the field of milk production, the most relevant selection criteria are identified as the ability of these technologies to process uncertain data and their ability to obtain accurate results in the best way. The analysis carried out supports the decision-making of milk production organization.

Keywords: *Multi-criteria analysis; Analytic hierarchy process; Prognosis; Policy decision*

ARTICLE INFO
Received: Sep 11, 2021
Accepted: Nov 13, 2021
Available online: Nov 19, 2021

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CITATION
Perdigón Llanes R, González Benítez N. Comparison and Selection of Artificial Intelligence Technology in Predicting Milk Yield 2021; 4(2): 63-71. doi: 10.32629/jai.v4i2.502

1. Introduction

Decisionmaking is an analytical process in which the best scheme is selected from multiple schemes in order to achieve a specific goal[1]. This activity is widely used in organizations because managers often need to make decisions on different issues[1,2]. The decision-making of milk production organization is a key factor to improve its production and economic indicators[3]. However, this process is sometimes carried out in the absence of information, which needs to improve its efficiency and accuracy[3].

Forecasting is a useful tool for decision-making in the dairy industry[4,5]. Accurate prediction of milk production can help improve the financial planning of milk producers and avoid economic losses[6-8]. In addition, it can improve cattle management, save farm energy and optimize long-term capital investment[4,5].

At present, different models are used to predict milk production[9]. These models are based on the application of mathematical, random time series, regression and computational algorithms based on artificial intelligence (AI) technology[9,10].

The use of AI technology in agricultural and livestock activities is a growing phenomenon that helps to improve data processing and the profitability of the sector's business[10-12]. Artificial intelligence techniques used in the literature to predict milk production include:

(1) Artificial Neural Network based technology (ANN)[5,10,13-19]

(2) Technology based on Support Vector Machine (SVM)[4,8,20]

(3) Genetic Algorithm based technology (GA)[4,19,21]

(4) Decision Tree based technology (DT)[8,22-24]

These techniques exhibit appropriate behavior for prediction in different fields because they have no restrictions on processing a large number of data and input variables, and can identify, learn and approximate data characteristics by simulating the inherent and nonlinear relationships existing in the data[11,25,26]. In addition, they can obtain accurate results by saving time and computing resources[8].

Artificial intelligence technology enables the agricultural sector to solve specific problems and make effective predictions in an environment with specific characteristics and variables based on its analysis[28]. However, milk production is influenced by various factors that hinder the prediction of milk production[4,9]. Climate change, livestock management, feeding, genetic and physiological characteristics and the incidence of diseases are some factors affecting milk production and complex prognosis[9]. Defining a model or technology to predict the effective performance of these products in different environments is a challenging and complex activity, because accurate models or technologies are not required in all scenarios[5,17,28].

Determining the AI technology most suitable for milk yield prediction is a concern of the international scientific community[8,25,29]. However, in the literature, there is no consensus on the best performance of artificial intelligence technology in this process. In addition, the identified authors take their prediction accuracy as the basic standard for evaluating the effectiveness of these technologies. This factor depends on the environmental factors (prediction variables) for prediction, which may be insufficient according to the characteristics of the decision-making environment (time, available data and resources, interpretability and applicability). The diversity of algorithms applicable to each AI Based Prediction Technology identified in the literature complicates the use of statistical analysis as a method to determine the technology most suitable for these product predictions.

Multi criteria decision making (MCDM) has proved satisfactory results in different application fields, especially when decisions need to be made between different alternatives according to different selection criteria or views[30]. Analytic hierarchy process (AHP) is one of the most commonly used MCDM methods in the literature because of its relevance and practical application[31,32], which is mainly used in Agricultural Research on the selection of production mode of dairy farms[33]. Its main advantage lies in dealing with quantitative (information and data obtained) and qualitative (views of decision makers and characteristics of decision environment) in the decision-making process[31,32,34].

The purpose of this study is to compare the application of artificial intelligence technology in milk yield prediction, and select the most suitable method for milk yield prediction by using analytic hierarchy process according to different selection criteria.

1.1. Selective analytic hierarchy process

It provides effective mathematical support for the analysis of selection problems; it measures quantitative and qualitative standards through a common scale; it allows errors in the evaluation process to be verified based on the inconsistency index and allows the results to be supplemented by other mathematical optimization methods[35]. This study is divided into three basic parts: materials and methods or calculation methods. The part describes the scientific methods and methods used in the research; The results and discussion section describes the main findings obtained in the application of AHP and its comparison with other studies related to the use of artificial intelligence technology for milk prediction; Finally, the conclusion is given.

2. Materials and methods or calculation method

This study adopts the methods of comprehensive analysis, investigation and experiment. The comprehensive analysis method allows the analysis and synthesis of literature related to the prediction and decision-making of the dairy industry. Through the questionnaire survey, the evaluation and judgment of experts on the application of analytic hierarchy process are obtained. A case study on the application of analytic hierarchy process is carried out by experimental method, in order to select the most suitable artificial intelligence technology for milk yield prediction. The procedure proposed in its study[36]was adopted as the method of implementing AHP. **Figure 1** depicts this process.

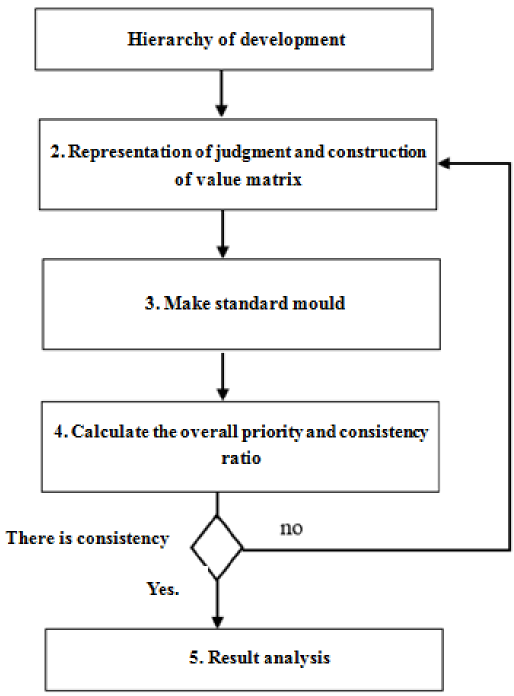

Figure 1. Methodology for implementing AHP[36].

15 national experts with high professional level and experience in artificial intelligence (100% experts) and animal husbandry (80% experts) compared the alternatives according to the selection criteria. Experts are selected through curriculum analysis, taking into account their university degrees, scientific categories, academic publications, mastery of relevant topics and research experience. All experts are doctors of science, and 66.67% of the experts have more than 10 years of research experience. The experts consulted were from the following institutions: Gene company "Camilo Cienfuegos" (2 experts), Universidad de Pinar del Río (2 experts), Provincial Meteorological Center of Pinar del Río (1 expert), Havana Agricultural University (4 experts), Institute of Agricultural Engineering (4 experts) and Universidad de Camagüey (2 experts).

The correct selection of experts is helpful to reduce the error and uncertainty in the process of scheme comparison. In order to prioritize options based on the selected comparison criteria and to improve the certainty of the process, the scale described in **Table 1**[37]was used. The scale allows a degree of certainty and homogeneity to determine the importance or preference of alternatives in the comparison matrix[36].

Table 1. The scale used to measure expert judgment[37].

Numerical scale	Speech scale	Description of
1	Equally important	These two elements contribute equally to ownership or standards
3	This factor is more important than another factor.	Judgment and experience tend to one factor rather than another
5	Element is more important than another element	Previous judgments and experiences strongly favor one factor over another
7	The importance of an element is strong relative to another element	Element strong domination
9	The importance of an element is extreme relative to another element	One element dominates another by the highest possible order of magnitude
2,4,6,8	Intermediate value between two adjacent judgments	

3. Results and discussion

3.1. Development hierarchy

Figure 2 depicts the hierarchical analysis performed in this study. At the top of the hierarchy are analysis objectives, comparison criteria at the middle level and alternatives at the lower level.

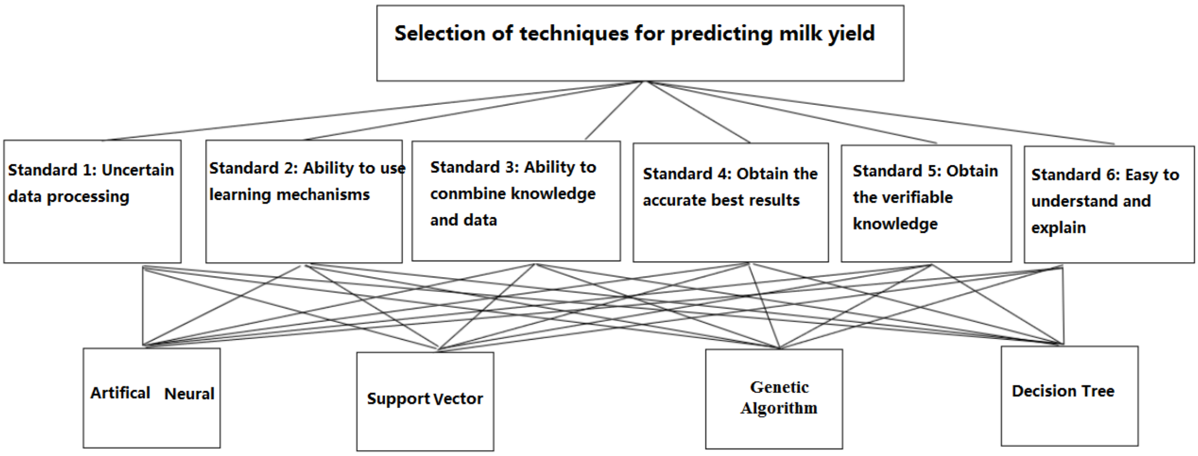

Figure 2. Hierarchy analysis.

Source: self compiled.

These criteria were selected based on a review of the literature on livestock forecasting: the processing of uncertain data[4,16], the use of learning mechanisms[12], the combination of knowledge and data[12], the best accurate results[8,9,29], Gain verifiable knowledge[12], easy to understand and interpret[27].

The alternatives evaluated in this study consist of AI technologies identified in the references. According to[27], these algorithms are not listed as alternative algorithms based on regression, because in recent years, they have only been used as comparative methods in milk production management research, indicating that the yield is lower than other AI technologies. The selected alternatives bring together different algorithms classified according to the following criteria[38]and[27]:

1. ANN-based techniques*: adaptive neuro fuzzy inference system,* symmetrical artificial neural network, *nonlinear autoregressive model with external input,* multilayer perceptron, *back propagation neural network, convolution neural network and long-term and short-term memory network* (LSTM).
2. SVM-based techniques: *support vector regression.*
3. GA-based techniques: simple classical genetic algorithm.
4. DT-based technology: random forest, statistical decision tree, regression tree and classification.

3.2. Representation of judgment and construction of value matrix

Through the questionnaire survey of the expert group, the expert group can make value judgments on the selection criteria and options. Seven n × n pair comparison matrices were prepared, and the experts evaluated the selection criteria and alternatives of assumptions based on these matrices. **Table 2** shows the value matrix based on expert evaluation.

In each matrix, the elements of row i = 1, 2,..., n are rated according to the proportional value described in **Table 1** relative to the elements of column j = 1, 2,..., n. This process is performed by aji = 1/K if the AIJ element of the comparison matrix A is k, and then aii = 1 for all diagonal elements because they are self-evaluated[37]. The geometric mean is used to synthesize the consensus judgment of experts because it provides sufficient accuracy in this process[36].

Table 2. Consensus evaluation matrix

a. Standard comparison matrix

	Standard 1	Standard 2	Standard 3	Standard 4	Standard 5	Standard 6
Standard 1	1	2	3	2	4	2
Standard 2	1/2	1	5	1/3	1/3	1/3
Standard 3	1/4	1/5	1	1/7	1/3	1/5
Standard 4	1/2	3	7	1	5	2
Standard 5	1/3	3	3	1/5	1	1/2
Standard 6	1/2	3	5	1/2	2	1

b. Comparison matrix 1

	ANN	SVM	GA	DT
ANN	1	3	8	3
SVM	1/3	1	5	1/3
GA	1/8	1/5	1	1/6
DT	1/3	3	6	1

c. Standard 2 Comparison Matrix

	ANN	SVM	GA	DT
ANN	1	6	9	8
SVM	1/6	1	4	5
GA	1/9	1/4	1	2
DT	1/8	1/5	1/2	1

d. Standard comparison matrix 3

	ANN	SVM	GA	DT
ANN	1	2	5	2
SVM	1/2	1	8	1/2
GA	1/5	1/8	1	1/7
DT	1/2	2	7	1

e. Standard comparison matrix 4

	ANN	SVM	GA	DT
ANN	1	1/2	4	5
SVM	2	1	3	4
GA	1/4	1/3	1	1/2
DT	1/5	1/4	2	1

f. Standard comparison matrix 5

	ANN	SVM	GA	DT
ANN	1	3	8	2
SVM	1/3	1	6	1/3
GA	1/8	1/6	1	1/4
DT	1/2	3	4	1

.g. Standard comparison matrix 6

	ANN	SVM	GA	DT
ANN	1	1/2	1/6	1/7
SVM	2	1	1/6	1/7
GA	6	6	1	1/3
DT	7	7	3	1

3.3. Manufacture of standardized mould

To standardize the comparison matrix, divide the elements of each comparison matrix by the sum of the values in the corresponding column. The priority vector is calculated by averaging each row of the normalization matrix. **Table 3** shows the normalization matrix and its respective priority vectors.

The priority vector represents the preference of the alternative relative to the standard under consideration. The results in **Table 3a** show that the ability to process uncertain data and obtain the best accurate results are the most relevant criteria for selecting the AI technology most suitable for milk production prediction. According to these standards, it is found that artificial neural network is more effective in dealing with uncertain data (**Table 3b**), support vector machine obtains accurate results while saving time and computing resources, followed by artificial neural network (**Table 3e**). In addition, there is evidence that DTS is an artificial intelligence technology that provides a better understanding and interpretation of its functions in the prediction process (**Table 3g**).

Table 3. Normalization matrix and its priority vector

a. Standardization matrix and priority vector comparison standard

	Standard 1	Standard 2	Standard 3	Standard 4	Standard 5	Standard 6	Priority vector
Standard 1	0.32	0.16	0.13	0.48	0.32	0.33	0.29
Standard 2	0.16	0.08	0.208	0.08	0.03	0.06	0.10
Standard 3	0.08	0.02	0.04	0.03	0.03	0.03	0.04
Standard 4	0.16	0.25	0.29	0.24	0.39	0.33	0.28
Standard 5	0.11	0.25	0.13	0.05	0.08	0.08	0.11
Standard 6	0.16	0.25	0.21	0.12	0.16	0.17	0.18
Total	1	1	1	1	1	1	1

b. Normalized matrix and priority vector of standard 1

	ANN	SVM	GA	DT	**Priority vector**
ANN	0.558	0.417	0.400	0.667	0.51
SVMe	0.186	0.139	0.250	0.074	0.16
GA	0.070	0.028	0.050	0.037	0.05
DT	0.186	0.417	0.300	0.222	0.28
Total	1	1	1	1	1

c. Normalized matrix and priority vector of standard 2

	ANN	SVM	GA	DT	**Priority vector**
ANN	0.713	0.805	0.621	0.500	0.66
SVM	0.119	0.134	0.276	0.313	0.21
GA	0.079	0.034	0.069	0.125	0.08
DT	0.089	0.027	0.034	0.063	0.05
Total	1	1	1	1	1

d. Normalized matrix and priority vector of standard 3

	ANN	SVM	GA	DT	**Priority vector**
ANN	0.455	0.390	0.238	0.549	0.41
SVM	0.227	0.195	0.381	0.137	0.24
GA	0.091	0.024	0.048	0.039	0.05
DT	0.227	0.390	0.333	0.275	0.31
Total	1	1	1	1	1

e. Normalized matrix and priority vector of standard 4

	ANN	SVM	GA	DT	**Priority vector**
ANN	0.290	0.240	0.400	0.476	0.35
SVM	0.580	0.480	0.300	0.381	0.44
GA	0.072	0.160	0.100	0.048	0.10
DT	0.058	0.120	0.200	0.095	0.12
Total	1	1	1	1	1

f. Standardized matrix and vector priority criterion 5

	ANN	SVM	GA	DT	**Priority vector**
ANN	0.511	0.419	0.421	0.558	0.48
SVM	0.170	0.140	0.316	0.093	0.18
GA	0.064	0.023	0.053	0.070	0.05
DT	0.255	0.419	0.211	0.279	0.29
Total	1	1	1	1	1

g. Normalized matrix and priority vector 6

	ANN	SVM	GA	DT	**Priority vector**
ANN	0.063	0.034	0.038	0.088	0.06
SVM	0.125	0.069	0.038	0.088	0.08
GA	0.375	0.414	0.231	0.206	0.31
DT	0.438	0.483	0.692	0.618	0.56
Total	1	1	1	1	1

Table 4. Priority matrix

	Standard 1	**Standard 2**	**Standard 3**	**Standard 4**	**Standard 5**	**Standard 6**	**Priority vector**
ANN	0.51	0.66	0.41	0.35	0.48	0.06	0.39
SVM	0.16	0.21	0.24	0.44	0.18	0.08	0.23
GA	0.05	0.08	0.05	0.10	0.05	0.31	0.11
DT	0.28	0.05	0.31	0.12	0.29	0.56	0.26

3.4. Calculation of global priority and consistency relation vector

According to the standards listed in **Tables 3b**, **3c**, **3d**, **3e**, **3f** and **3g** respectively, a priority matrix is established, which contains the priority vector of the alternative and is used to calculate the global priority vector of the alternative. **Table 4** shows the constructed priority matrix and the global priority vector of alternatives.

The overall priority vector of alternatives represents their preference level and constitutes a solution judged by experts[36]. In order to determine its value, the standard priority vector obtained in **Table**

3a is multiplied by the priority matrix listed in **Table 4**. The global priority vector shows that the technology based on artificial neural network and decision tree constitutes an artificial intelligence technology with better fitting for milk yield prediction with preference index of 0.39 and 0.26 respectively.

In order to verify the results of this study, we calculated the consistency ratio of each comparison matrix. RC represents the reasonableness of the judgment used in the comparison matrix and is calculated by dividing the consistency index (CI) by the random consistency index (RI)[36]. Formulas 1 and 2 illustrate how to determine the size of these indexes respectively.

$$\mathrm{IC} = \frac{\lambda\max - n}{n-1} \quad (1)$$

$$\mathrm{IA} = \frac{1.98(n-2)}{n} \quad (2)$$

Where

n: compare the number of elements in the matrix to be evaluated.

λmax: the average value of vector elements, which is obtained by multiplying the comparison matrix by its respective priority vector and the product of the latter.

According to Saaty[39] , if RC < 0.10, the degree of inconsistency in judgment is acceptable, otherwise experts must reassess their evaluation. **Table 5** shows the RC values of the comparison matrix.

Table 5. Consistency relationship of comparison matrix

Matrix comparison	Reinforced
Comparison standard	0.091
Uncertain data processing	0.067
Ability to use learning mechanism	0.079
Ability to combine knowledge and data	0.078
Get accurate results in the best way	0.079
Gain verifiable knowledge	0.075
Easy to understand and explain	0.060

The results in **Table 5** show that the degree of inconsistency in peer comparison is acceptable, which indicates that there is no contradiction in the judgment of experts.

4. Result analysis

The RC index described in **Table 5** can infer that the execution of the expert judgment process is correct. The results show that the artificial intelligence technology based on artificial neural network is more suitable for predicting milk yield with 39% preference level than the technology based on decision tree and support vector machine (26% and 23% respectively).

In their analysis[29], they found that NARX artificial neural network can improve the accuracy of milk yield prediction better than the model based on multiple linear regression and static artificial neural network technology. The author[38]determined that the most used artificial intelligence technologies in animal husbandry production related research during 2004–2018 were support vector machine and artificial neural network. In their study[8], they compared the performance of three prediction models to predict the milk yield of Holstein Frisian varieties using neural network, support vector machine and random forest techniques, respectively. The experimental results show that the model based on support vector machine has high accuracy and computational complexity. According to[19], using GA in LSTM network can obtain more accurate milk yield prediction than the model based on ANN-LSTM only[27]. A retrospective study of dairy farm management from 2010 to 2020 shows that artificial neural network and DT are the best performing artificial intelligence technologies in this field. Consistent with the research results of Slob, Catal and Kassahun[26], this study shows that the artificial intelligence technology based on artificial neural network and DT provides the best performance for predicting milk yield respectively.

5. Conclusion

With the application of analytic hierarchy process, the technology based on artificial neural network is considered to be the most suitable technology for milk yield prediction, which is better than the technology based on decision tree and support vector machine. In addition, there is evidence that the ability to process uncertain data and obtain accurate results in the best way are the most relevant selection criteria for evaluating AI technologies applied to milk yield prediction.

This study is helpful to the decision-making of milk production organization and the development of prediction model of dairy industry. Future work can be used to evaluate the performance of different types of artificial neural networks in predicting milk yield and determine the correlation between their characteristics and their efficiency as a prediction tool.

Conflict of interest

The authors declare that they have no conflict of interest.

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