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A New Idea in Animal Science: The First Application of the Analytical Hierarchy Process (AHP) Model in Selection of the Best Dairy Cow

Research Article

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ABSTRACT

The final goal of all dairy cow raising systems in the world is to use the available capacities and the cooperation of other sectors in order to solve the problems and issues, such as the limitations in time, man power and financial resources, for providing a complete answer. Therefore, the need for optimization of cow raising systems by prioritization of measures and plans is the most obvious challenge before experts and farmers working in the field of raising dairy cow. This paper is focused on introduction and analysis of the AHP as one of the renowned methods of multiple criteria decision making for the prioritization of selection of dairy cow. The present paper has for the first time in the world used the AHP approach and Expert Choice11.1 software to animal of production. Using expert opinions in the present study, the selection of the best dairy cow from among the 10 Holstein cows being studied was done according to priorities. The dairy cows tested in this study were all 4 years old and had completed 2 full parities of milking of 305 days. They were in the third parity period. At the end, dynamic and sensitivity analysis was performed to clarify the final sensitivity of the decision in the judgments. Based on produced results for criteria such as milk production rate, % of milk fat, % of milk protein, milk somatic cell counts (SCC) and animal body weight (kg) respectively, with priority vectors of 0.437, 0.234, 0.134, 0.090 and 0.104 were known the priorities needed by the experts. Afterwards, data was collected by questionnaires analyzed by the Expert Choice 11.1 software (Expert Choice Inc., 1986). The best dairy cow defined according to high milk production rate, suitable fat content, protein content, milk somatic cell counts and body weight. Then, by AHP were calculated priority vectors of the dairy cows: A (0.099), B (0.101), C (0.098), D (0.096), E (0.095), F (0.102), G (0.120), H (0.73), I (0.107), J (0.109). Therefore, by recording and Delphi methods and also, according to traits priority vectors, was selected dairy cow G as the best cow in the study. So the AHP will be very useful in future in animal science.

KEY WORDS analytical hierarchy process (ahp), animal science, dairy cow, selection.

INTRODUCTION

Measures and criteria are needed to assess any subject. The choice of proper measures and criteria provides us with a chance of having proper comparisons between the available alternatives. The AHP is a decision support tool, defined as a multiple-criteria decision making approach (Vaidya and Kumar, 2006). The use of multiple criteria however makes the assessment process complex, and the complexity increases as the multiple criteria have various and contradicting natures. Under such conditions the assessment and comparison process is no longer a simple analysis that the human mind cannot handle, and its scientific analysis requires more accurate tools. AHP is one of the most common tools of multiple-criteria decision making (Franzel *et al.* 1996). AHP is a flexible and strong method for making decisions when facing numerous and sometimes contradicting criteria. This multiple-criteria assessment method was first proposed in 1980 by Thomas L. Saaty for expression of multiple-criteria decisions, and since then it has been widely used in various areas of science and provides a structured yet relatively simple solution to the decision making problems. The method is a set of various integrated measurements inside a general section for assessment of decision options. Its main feature is that it is based on pairwise comparisons (Saaty, 1990). Selection of the best dairy cow in all raising aspects is one of the most important results of dairy cow management which is in need of multiple-criteria decision making. The present paper its goal is to select the best dairy cow (goal) from among 10 dairy cows (Holstein) in terms of priorities defined by experts by means of questionnaires.

As the first step, the goal of the study was defined as selecting the best dairy cow. Then the criteria of selection were defined: production of milk, fat content, protein content, milk somatic cell counts and animal body weight. The available alternatives for dairy cow included in the study were also considered. The work procedure includes defining the goal through assessment of some alternatives with multiple-criteria, grading the best alternative according to selected criteria, and then using them to set the path and the goal. After that the priority vectors are set in a different process and the alternatives are then graded accordingly with results. This method is widely used due to its simplicity, flexibility, simultaneous use of quantitative and qualitative measures, capacity to study adaptations in judgments (Ramanathan and Ganesh, 1995). It can thus be used effectively for assessments and decision makings related to management of animals with various quantitative and qualitative characteristics. Aims this study is selection of dairy cow with high milk production, high % of fat and % of protein, low SCC and high body weight. In order to determine the best dairy cow will create the hierarchical structure and to compare of results and we will see (Figure 1).

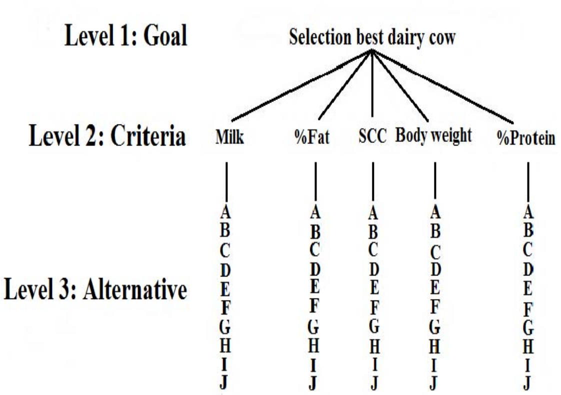

Figure 1 Flowchart of the AHP

MATERIALS AND METHODS

At this stage, the criteria are compared pair by pair. The significance of each criterion is defined in relation to the other criteria. For this purpose one can use a standard method (e.g. that of Saaty). The procedure includes assigning a number from 1 to 9 to each pairwise comparison, such that the meaning of each number is defined in Table 2. For example, in this study for the selection of dairy cow, the producer may prefer the milk production rate to somatic cell counts multiple times. Thus, once the relative weight of all criteria are set by experts by means of geometric mean, the weight of each criterion in relation to another criterion is defined. In order to introduce the new method and provide a more accurate assessment, the test day of milk production, fat content, protein content, somatic cell counts and body weight of 10 cows of Holstein breed were used. The method of research in various stages of the study was as follows:

Recording method

In order to access the information available in records of Mashhad city, Iran Holstein dairy cows, the records used in this study were selected in a random method on the test day. The dairy cows tested in this study were all 4 years old and had completed 2 full parities of milking of 305 days. They were in the third parity period (Table 1).

Delphi method

To define the assessment criteria in this method each professor and expert was given a separate questionnaire containing all related criteria (so that each of them gave a score of 1 to 9 for each criterion). Thus, according to Table 2; 14 questionnaires were distributed among professors and experts on the raising of dairy cow asking them about the level of priority of the criteria including 5 criteria as the decisive criterion: milk production rate, fat content, protein content, milk somatic cell counts (SCC) and animal body weight. The questionnaires were collected through analysis by Expert Choice 11.1 version software. The results of the questionnaires demonstrated that in the opinion of the experts, priority vector to milk production rate (0.437), fat content (0.234), protein content (0.134), body weight (0.104) and milk somatic cell counts (0.090) had the highest rates of priority (Table 4). The reasons provided by the experts were: 1. significance of producing large amounts of milk at dairy farms for which all farmers and professionals in the field of animal production must do their best; 2. since the price of the milk is set at dairy factories according to fat and protein content, the next level of importance is given to this measure; 3. with has a direct effect on the milk production rate; 4. due to lack of particular registration unit for somatic cell counts in the milk produced by each dairy

Table 1 Holstein dairy cow data

	A	B	C	D	E	F	G	H	I	J
Milk (kg)	41.4	33.4	36.4	33.0	30.4	39.8	46.6	27.5	45.0	40.8
%Fat	2.98	3.22	2.84	2.92	3.19	3.11	3.29	3.07	3.42	3.62
%Protein	2.96	3.58	3.22	3.38	2.97	2.86	3.10	2.83	2.90	3.00
SCC	155	141	149	147	125	132	155	139	176	140
Body weight (kg)	625	610	651	672	593	616	733	582	684	696

SCC: somatic cell counts.

farm, and also lack of regular registration of the records that results in high variance of the records, all experts assigned the lowest level of importance to this factor. The SCC has an important role in identified cow with mastitis. This method can even be identified with the patient cow.

Steps for applying the AHP:

1: define the problem and determine its goal.

2: structure the hierarchy from the top (the objectives from a decision maker's viewpoint) through the intermediate levels (criteria on which subsequent levels depend) to the lowest level which usually contains the list of alternatives.

3: construct a set of pairwise comparison matrices (size n×n) for each of the lower levels with one matrix for each element in the level immediately above by using the relative scale measurement shown in Table 2. The pairwise comparisons are done in terms of which element dominates the other.

4: there are n (n_1) dividing to judgments required to develop the set of matrixes in step 3. Reciprocals are automatically assigned in each pairwise comparison.

5: hierarchical synthesis is now used to weight the eigenvectors by the weights of the criteria and the sum is taken overall weighted eigenvector entries corresponding to those in the next lower level of the hierarchy.

6: having made all the pairwise comparisons, the consistency is determined by using the eigenvalue, λ_{max}, to calculate the consistency index, (CI) as follows:

$$CI= (\lambda_{max}-n) / (n-1)$$

Where:

n: matrix size.

Table 2 Pairwise comparison scale for AHP preference

Numerical rating	Explanation of numerical preference score
9	Extremely preferred
8	Very strongly to extremely
7	Very strongly preferred
6	Strongly to very strongly
5	Strongly preferred
4	Moderately to strongly
3	Moderately preferred
2	Equally to moderately
1	Equally preferred

Saaty (1977) Judgment consistency can be checked by taking the consistency ratio (CR) of CI with the appropriate value in Table 3. The CR is acceptable, if it does not exceed 0.1. If it is more, the judgment matrix is inconsistent. To obtain a consistent matrix, judgments should be reviewed and improved.

Determine the criteria and alternatives weights

This step determines the weights of each criteria and alternative. In an AHP process once are set the criteria, it is time to set the alternatives weight (priority vector). After calculating the weights of criteria and alternatives, can be obtained the final weight of each criteria (Table 4). Consistency of the analysis, if the value is less than 0.1, the comparisons are acceptable consistency, otherwise you need to reconsider the comparisons. The consistency rate is:

$$CR=CI/RI$$

Where:

RI: is a random index fit matrix is shown in Table 3.

The priority of each alternative is judged in relation to each criterion of the study. The process of calculating the weight of each alternative (priority vector) in relation to each criterion is quite similar to the process for setting the priority vector of criteria in relation to the goal. In both cases, judgments are based on pairwise comparisons of criteria and alternatives and based on the 9 value scales of Saaty. Thus the pairwise comparison matrix of the criteria is completed and the required priority vectors are obtained (Saaty and Kearns, 1991).

The following we done:

1: synthesizing the pairwise comparison matrix (Table 4).

2: calculating the alternatives priority for a criterion such as (Table 10). 3. Calculating the consistency ratio.

4: calculating λ_{max}.

5: calculating the consistency index, CI.

6: selecting appropriate value of the random consistency ratio from (Table 3).

7: checking the consistency of the pairwise comparison matrix to check whether the decision maker's comparisons were consistent or not.

λ max: 5.246; CI: 0.0615; RI: 1.12; CR: 0.0549<0.1.

Σ =1.000; Inconsistency: 0.04.

In Tables 5,6,7,8 and 9 the data for each dairy cow were obtained through analysis by Expert Choice 11.1 software and prioritization of each dairy cow in connection with the criterion in question. The obtained data for each dairy cow was compared with the data for other cow in pairwise comparisons. Negative numbers show the loss of performance for each dairy cow in comparison with other dairy cow. The following tables provide information on priorities of all dairy cows, showing the superiority of each cow according to related criteria. At this stage, the Expert Choice software can do the rest automatically combine the criterion priorities and the priorities of each decision alternative relative to each criterion in order to develop an overall priority ranking of the decision alternative which is termed as the priority matrix (Table 10).

In the present study an AHP method was employed by means of Expert Choice software to determine the ranks of the dairy cow and analyze the results. Moreover, the results were obtained in the form of various numbers showing the conditions of different cows. The highest rank indicated a better milk production in comparison to other cow. In other words, the ranking was made of the total scores obtained for all criteria for each dairy cow. In order to facilitate the selection of the best alternative (dairy cow), and taking into account the number of the cow, all 10 cows were ordered in descending order based on their ranks in Diagram 1 entitled analysis of performance sensitivity and also in Table 10.

The results of the best alternative were for cow G with a score of 0.120, while the lowest rank was for cow H with a score of 0.073. It must be noted that in the present study the daily production records of the dairy cow were used in order to provide a more accurate analysis of the AHP approach. In order to reduce the bulk of available data for each animal and less need for processing power and time, one could simply use the milk records of 305 days of each cow (test day). Thus, the paper has for the first time applied Expert Choice software to management of dairy cow. At the end, each dairy cow was ranked according to the 9 criteria. Therefore, given the characteristics of this method in analyzing quantitative and qualitative traits, it may be well used for larger numbers and more traits of cow. So, the results of this study may be considered for more accurate monitoring of ratios and coefficients used by experts in order to facilitate the selection process. Based on the methods of taking records from the cattle, milk production traits were of low-inheritance properties and their selection precision rates were also different. For instance, according to date in record 1 of dairy cattle, the produced milk rate had 3% inheritability and its selection precision will be 55%, while the same precision for the same trait will be 67% for records 10 (Bourdon,1999).

Thus, in the present study efforts were focused on setting the selection index on the individual records of each animal (selection is often made according to results of male cattle).

Table 3 Average random index (RI) for corresponding matrix size from Saaty (1977)

Size of matrix	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

RI: random index.

Table 4 Modified pairwise comparison matrix for the five criteria

	Milk	%Fat	%Protein	SCC	Body weight	Priority
Milk	1	2	3	4	6	0.437
%Fat	1/2	1	2	3	2	0.234
%Protein	1/3	1/2	1	2	1	0.134
somatic cell counts	1/4	1/3	1/2	1	2	0.090
Body weight	1/6	1/2	1	1/2	1	0.104

SCC: somatic cell counts.

Table 5 Pairwise comparison matrix for milk production

A	B	C	D	E	F	G	H	I	J	Priority
A	1.239	1.137	1.254	1.361	1.040	1.125	1.505	1.087	1.014	0.047
B		1.089	1.012	1.098	1.191	1.395	1.214	1.347	1.221	0.038
C			1.103	1.197	1.093	1.280	1.323	1.236	1.120	0.041
D				1.085	1.206	1.412	1.200	1.363	1.236	0.038
E					1.309	1.523	1.105	1.480	1.342	0.031
F						1.170	1.447	1.130	1.025	0.045
G							1.694	1.035	1.142	0.058
H								1.636	1.483	0.020
I									1.103	0.053
J										0.046

Inconsistency: 0.00.
Σ: 0.437.

Table 6 Pairwise comparison matrix for % of fat

A	B	C	D	E	F	G	H	I	J	Priority
A	1.080	1.040	1.020	1.070	1.040	1.137	1.030	1.147	1.214	0.025
B		1.133	1.102	1.009	1.035	1.052	1.048	1.062	1.124	0.027
C			1.028	1.123	1.095	1.193	1.080	1.204	1.274	0.024
D				1.092	1.065	1.160	1.051	1.171	1.239	0.025
E					1.025	1.062	1.039	1.072	1.134	0.027
F						1.090	1.013	1.099	1.163	0.027
G							1.104	1.008	1.067	0.029
H								1.114	1.179	0.026
I									1.058	0.029
J										0.031

Inconsistency: 0.00.
Σ: 0.234.

Table 7 Pairwise comparison matrix for % of protein

A	B	C	D	E	F	G	H	I	J	Priority
A	1.209	1.087	1.141	1.052	1.003	1.047	1.046	1.020	1.013	0.011
B		1.111	1.059	1.205	1.251	1.154	1.265	1.234	1.193	0.018
C			1.049	1.084	1.125	1.038	1.137	1.110	1.073	0.016
D				1.138	1.181	1.090	1.194	1.165	1.126	0.017
E					1.038	1.043	1.049	1.024	1.010	0.012
F						1.084	1.010	1.014	1.049	0.010
G							1.095	1.069	1.033	0.016
H								1.024	1.060	0.010
I									1.034	0.011
J										0.012

Inconsistency: 0.00.
Σ: 0.134.

Table 8 Pairwise comparison matrix for milk somatic cell counts (SCC)

A	B	C	D	E	F	G	H	I	J	Priority
A	1.099	1.040	1.054	1.240	1.174	1.000	1.115	1.135	1.107	0.006
B		1.056	1.042	1.128	1.068	1.099	1.014	1.248	1.007	0.008
C			1.013	1.192	1.128	1.040	1.072	1.181	1.064	0.007
D				1.176	1.113	1.054	1.057	1.197	1.050	0.007
E					1.056	1.240	1.112	1.408	1.120	0.014
F						1.174	1.053	1.333	1.060	0.010
G							1.115	1.135	1.107	0.006
H								1.266	1.007	0.009
I									1.257	0.004
J										0.009

Inconsistency: 0.00.
Σ: 0.090.

Table 9 Pairwise comparison matrix for animal body weight.

A	B	C	D	E	F	G	H	I	J	Priority
A	1.020	1.040	1.070	1.050	1.010	1.170	1.070	1.090	1.110	0.010
B		1.060	1.100	1.050	1.010	1.200	1.070	1.120	1.140	0.009
C			1.030	1.090	1.050	1.120	1.110	1.050	1.060	0.010
D				1.130	1.090	1.090	1.150	1.010	1.030	0.010
E					1.030	1.230	1.010	1.150	1.170	0.009
F						1.190	1.050	1.110	1.120	0.009
G							1.250	1.070	1.050	0.012
H								1.170	1.190	0.009
I									1.010	0.011
J										0.011

Inconsistency = 0.00.
Σ = 0.104.

Since generations of dairy cattle are naturally quite far apart, the time needed for the daughters of the same cow to reach milk production phase will at least be 24 months (due to slow growth of breasts in the first round, the daughters cannot show their true milk production potentials). It takes time. In view of the needs of the breeders for quick and effective decisions, it seems that AHP method can help a lot in the management of cattle farms. It must be noted that the software is capable of analyzing the co-variance of multiple traits at the same time.

Table 10 Priority matrix for dairy cow selection

	Milk	%Fat	%Protein	SCC	Body weight	Overallpriority
A	0.047	0.025	0.011	0.006	0.01	0.099
B	0.038	0.027	0.018	0.008	0.009	0.101
C	0.041	0.024	0.016	0.007	0.01	0.098
D	0.038	0.025	0.017	0.007	0.01	0.096
E	0.031	0.027	0.012	0.014	0.009	0.095
F	0.045	0.027	0.01	0.01	0.009	0.102
G	0.058	0.029	0.016	0.006	0.012	0.120
H	0.02	0.026	0.01	0.009	0.009	0.073
I	0.053	0.029	0.011	0.004	0.011	0.107
J	0.046	0.031	0.012	0.009	0.011	0.109

Inconsistency: 0.00.
Σ: 0.100.
SCC: somatic cell counts.

Performance sensitivity analysis

The relative importance of each alternative compared to other alternatives in terms of objective criteria and overall show. The overall objective of the priority of each alternative to see charts and graphs intersection with the vertical line overall and read the numbers on the right Y-axis is performed. The criteria for determining the priority of each alternative, seeing the intersection of the vertical line graphs with the scale and read the numbers on the left Y-axis is determined by the level of importance (Figure 1).

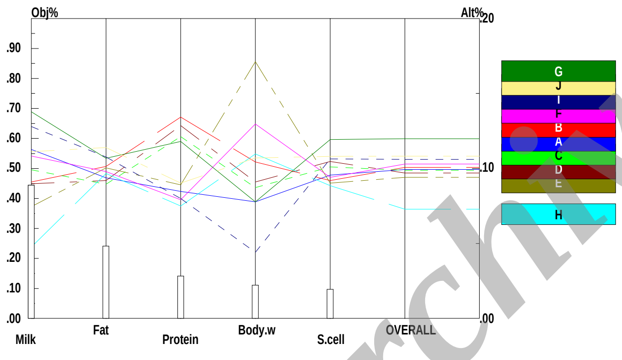

Figure 2 Performance sensitivity analysis

Dynamic sensitivity analysis

This analysis is sensitive to changes in priorities, criteria, and how the priorities criterion indicates the priority of other criteria. Dynamic sensitivity analysis enables us to that increase or decrease the priority of one or more criteria, changes to view the preference alternatives (Figure 2). The present paper has for the first time in the world used of multiple-criteria decisions by AHP method and its software to animal science and selection best of the dairy cow.

The pair-wise comparisons leading to priority weights can be misleading if care is not taken. The implication of this from a decision making perspective is that the evaluation stage of the decision becomes crucial after the selection process. Therefore, final decisions need to be re-examined to prevent potential mistakes. The presented combined methodological framework (AHP) for decision support on

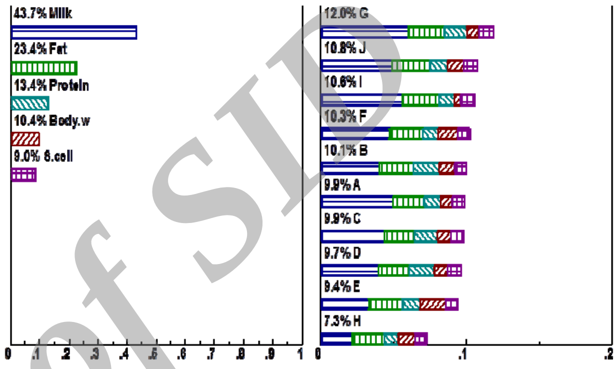

Figure 3 Dynamic sensitivity analysis

dairy cow could provide additional information support, bring additional clarity to the decision, and could therefore play an important role in further development of decision support systems on dairy cow.

CONCLUSION

As the results derived in this study are from a small sample, a caution should be taken in using these findings in a broader context. A large sample is highly desirable to capture greater heterogeneity in preferences and to make generalizations.

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