Formation of informative signs for predicting the disease of highly productive cows with non-communicable diseases

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Abstract. In this article, fuzzy set membership functions have been developed based on the main factors (clinical, morphochemical, rumen contents) to predict the following non-communicable diseases such as ketosis, osteodystrophy, secondary osteodystrophy and hypomicroelementosis in high-yielding cows. The results of the study show the high efficiency of the proposed decision-making algorithm for forecasting, classifying and measuring poorly formalized processes, that are described by fuzzy models. The available knowledge about the existing experimental data makes it possible to increase the adequacy of the fuzzy expert system.

1. Introduction
In fulfilling the tasks aimed at the development of animal husbandry on the basis of farm, dehkan and personal subsidiary plots, according to the Resolutions of the President of the Republic of Uzbekistan "Measures to stimulate the growth of livestock in personal subsidiary, dehkan and farm enterprises" (dated March 23, 2006, No. 308-PP) and "Extra measures to enhance incentives to increase the livestock population in personal subsidiary, dehkan and farms and expand livestock production" (dated April 21, 2008, No. 842-PP), special attention is paid to further increasing livestock productivity, increasing the profitability of the industry and ensuring the growing demand of the population for livestock products. Internal non-communicable diseases, among which the secondary osteodystrophy in cows occupies a significant place, are a significant obstacle in solving the assigned tasks. Analysis of literature data shows that the processes of acclimatization of imported cows in farms of the Republic, as well as the distribution, etiology, and features of the course of secondary osteodystrophy in cows, still remain insufficiently studied.

The etiology and pathogenesis of secondary osteodystrophy in imported, from foreign countries, highly productive cows are insufficiently disclosed and require further study. First of all, the issues of development and introduction into production of new effective methods of prevention and therapy of secondary osteodystrophy in cows are topical for science and practice. The modern development of science and technology is taking place in the world of complex systemic relations and a huge volume of information flows. Such conditions require new approaches to the analysis of emerging problems and the adoption of management decisions, based on the theoretical and applied apparatus of system analysis. A significant number of problems in the analysis of behavior and control of complex systems, including biological systems (man, society, animal) have to be solved in conditions of incomplete, fuzzy and indefinite assessments, when the use of the formalized language of traditional mathematics significantly impoverishes the mathematical model of decision-making that does not allow taking into account all the details of the problem situations and often leads to unsuccessful and incorrect decisions. Numerous studies of domestic and foreign scientists’ have
shown that for the successful solution of problems in conditions of fuzzy information, it is advisable to use the apparatus of fuzzy decision-making logic. However, the effectiveness of this apparatus for various problem situations has not been studied enough. There is no theoretical certainty in such issues as the choice of the type and parameters of membership functions, the aggregation of membership functions when solving problems with many variables, etc. [3]

2. Materials and methods
This material presents the results of constructing logic-linguistic models in the corresponding factor spaces, which make it possible to assess the likelihood of acute degenerative disease, secondary acute degenerative dystrophy and ketosis in cows. These research objects are dairy cows belonging to the farms of Pastdargom and Akdarya districts of Samarkand region. Black-and-white cows, aged 4-5 years, blood, milk, the contents of the rumen obtained from them, as well as bones obtained from forcibly slaughtered cows, patients with secondary osteodystrophy, as well as a preventive mixture of germinated grain with macro and microelements. [2] In order to determine the combined space of informative signs, a group of highly qualified experts was formed, Doctor of Veterinary Sciences, Professor B.M Eshburieva, and Doctor of Veterinary Sciences, Associate Professor Eshburieva S.B.

3. Formulation of the problem
The process of constructing a fuzzy-logical assessment model, classification and forecasting based on the investigated data are considered.
In general, it is required to build a model of the following type, consisting of conclusions about fuzzy rules [5].

\[
\bigcup_{n=1}^{k} \bigcap_{m=1}^{p} x_i = a_{i,jp} w_m \text{ with weight} \rightarrow y_r = f'(x_1, x_2, \ldots, x_n) \quad (1)
\]

find the values of the coefficients so as to minimize the following expression:

\[
\sum_{r=1}^{M} (y_r - y_r^f)^2 \rightarrow \min \quad (2)
\]

where \(y_r^f\) is the output of the input fuzzy rules based on the knowledge \(V\) of the input data of the \(r\)-row of the choice \(X_r\).

Here \(a_{i,jp}\)-linguistic term of variable \(x_i\) of the line \(jp\).
\(a_{i,jp}\) - linguistic term for evaluating a variable \(x_i\) of the line \(jp\).
\(w_m\) - weight coefficient of \(jp\)-fuzzy rules.
\(y_f\) = \(f_j(x_1, x_2, \ldots, x_n)\) - output of fuzzy rules.

The result of a fuzzy rule can be represented by fuzzy terms or represented by a linear relationship, depending on whether the model type is Mamdani or Sugeno.

This allows you to solve several existing (model) problems of classification, evaluation based on the constructed membership function and verification of comparison processes with the results of several algorithms. [5].

In this work, the membership functions of the parameters for assessing the state of animal disease are constructed. In this case, the tasks of assessment, classification and prognosis of the disease are solved on the basis of 17 signs. According to accepted clinical practice, the results of diagnostics of non-communicable diseases in high-yielding cows can be classified as follows: \(y_1\)-ketosis; \(y_2\)-osteodystrophy; \(y_3\)-secondary osteodystrophy; \(y_4\)-hypomicroelementosis.

We consider the listed \(y_1 - y_4\) stages of forecasting, which need to be recognized. While making diagnoses of osteodystrophy, ketosis, secondary osteodystrophy, hypomicroelementosis in high-yielding cows, the following main parameters are considered (possible values are indicated in brackets, including \(X_{1-17} \in \{0;1\}\) :
The underlying disease is diagnosed in accordance with accepted clinical practice. Based on the information provided, a list of diagnoses is compiled, and a numerical value is provided for each diagnosis. When making diagnoses of secondary osteodystrophy, osteodystrophy, ketosis, and hypomicroelementosis, we take into account the following main clinical factors:

1. Temperature °C
2. Pulse per minute
3. Breathing per minute
4. Ruminination, in two minutes
5. Erythrocyte count mln / μl
6. Hemoglobin, g / l by method (Sali Hemometer)
7. Total protein, g / l (by refractometry)
8. Total calcium, mmol / l (Vigev. Karakashov's method)
9. Organic phosphorus mmol / l (the method pulse by V.F.Kromyslov, with the modification by L.A.Kudryatsev)
10. Glucose, mmol / l (color reaction with orthotoluidine)
11. Reserve alkali (CO₂) vol% (by I.P. Kondrakhin's method)
12. Copper mmol / l
13. Cobalt mmol / l
14. Manganese mmol / l
15. Zinc mmol / l
16. The amount of infusoria in the rumen 1000 / ml
17. The Condition of rumen fluid (RA meter) [2].

The task of classification, diagnostics is to compare one of the solutions to each combination of parameter values $y_j$ ($j=1,4$)

4. Research results and discussion

4.1. Clinical factors

**Pulse in one minute.** Pulse of cows in one minute $x_2$: up to 50 times per minute - 0, 50 times per minute to 65 times per minute $- \frac{x-50}{65-50}$ from 65 times in one minute to 80 times in one minute $- \frac{80-x}{80-65}$, more than 80 times per minute - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$\mu(x_2) = \begin{cases} 
0, & \text{if } x \leq 50 \\
\frac{x-50}{65-50}, & \text{if } 50 < x \leq 65 \\
\frac{80-x}{80-65}, & \text{if } 65 < x \leq 80 \\
0, & \text{if } x \geq 80
\end{cases}$$

An important point in the diagnosis of cows' disease with secondary osteodystrophiad and its forms is...
an increase in the pulse rate in one minute.

**Breathing in one minute.** Breathing cows in one minute $x_3$: up to 12 times per minute - 0, from 12 times per minute to 18.5 times per minute - $\frac{x-12}{18.5-12}$ from 18.5 times per minute to 25 times per minute - $\frac{25-x}{25-18.5}$, more than 25 times in one minute - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$
\mu(x_3) = \begin{cases} 
0, & \text{if } x \leq 12 \\
\frac{x - 12}{18.5 - 12}, & \text{if } 12 < x \leq 18.5 \\
\frac{25 - x}{25 - 18.5}, & \text{if } 18.5 < x \leq 25 \\
0, & \text{if } x \geq 25
\end{cases}
$$

In the diagnosis of the disease of cows with secondary osteodystrophy, the disease ketosis is revealed and its forms are an increase in breathing in one minute.

**Rumination in two minutes.** Rumination of cows in two minutes $x_4$: up to 3 times every two minutes - 0, from 3 times every two minutes to 4 times every two minutes - $\frac{x-3}{4-3}$ from 4 times every two minutes up to 5 times every two minutes - $\frac{5-x}{5-4}$, more than 5 times in two minutes- 1. Confidence in belonging to $\mu(x)$ is described by the expression:

$$
\mu(x_4) = \begin{cases} 
0, & \text{if } x \leq 3 \\
\frac{x - 3}{4 - 3}, & \text{if } 3 < x \leq 4 \\
\frac{5 - x}{5 - 4}, & \text{if } 4 < x \leq 5 \\
0, & \text{if } x \geq 5
\end{cases}
$$

In the diagnosis of the disease of cows with secondary osteodystrophy, the disease ketosis is revealed and its forms are an increase in breathing in one minute.

**4.2. Biochemical factors**

**Erythrocyte.** Blood test of red blood cell count of cows $x_5$: up to 5 million / $\mu$L - 0, from 5 million / $\mu$L to 6.2 million / $\mu$L - $\frac{x-5}{6.2-5}$ from 6.2 million / $\mu$L to 7.5 million / $\mu$L - $\frac{7.5-x}{7.5-6.2}$, above 7.5 million / $\mu$L - 0. Confidence in belonging to $\mu(x)$ is described by the expression:
A decrease in the erythrocyte count in the blood by 16-33% in cows reveals the disease of acute dystrophy and hypomicroelementosis. **Hemoglobin method (Sali Hemometer).** During the exploratory analysis, a decrease in hemoglobin in cows was revealed: up to 99 g/l - 0, from 99 g/l to 114 g/l - \( \frac{x - 99}{114 - 99} \), from 114 g/l to 129 g/l - \( \frac{114 - x}{129 - 114} \), more than 129 g/l - 0. Confidence in belonging to \( \mu(x) \) is described by the expression:

\[
\mu(x) = \begin{cases} 
0, & \text{if } x \leq 99 \\
\frac{x - 99}{114 - 99}, & \text{if } 99 < x \leq 114 \\
\frac{114 - x}{129 - 114}, & \text{if } 114 < x \leq 129 \\
0, & \text{if } x \geq 129 
\end{cases}
\]

A 13-15% decrease in hemoglobin concentration in cows reveals ketosis disease and secondary acute degeneration. **Total protein g/l (by refractometry).** Total urine protein in cows: up to 68.3 g/l - 0, from 68.3 g/l to 73.4 g/l - \( \frac{x - 68,3}{73,4 - 68,3} \), from 73.4 g/l to 78.6 g/l - \( \frac{78,6 - x}{78,6 - 73,4} \), more than 78.6 g/l - 0. Confidence in belonging to \( \mu(x) \) is described by the expression:

\[
\mu(x) = \begin{cases} 
0, & \text{if } x \leq 68,3 \\
\frac{x - 68,3}{73,4 - 68,3}, & \text{if } 68,3 < x \leq 73,4 \\
\frac{73,4 - 68,3}{78,6 - x}, & \text{if } 73,4 < x \leq 78,6 \\
0, & \text{if } x \geq 78,6 
\end{cases}
\]
A decrease in the total protein index by 21-75% in cows reveals secondary acute dystrophy while an increase in the indicator by 86 g/l reveals ketosis disease. **Total calcium (Vigev. Karakashov’s method).** Total Calcium in the Cows $x_8$: up to 2.5 mmol/l - 0, from 2.5 mmol/l to 2.8 mmol/l - $\frac{x-2,5}{2,8-2,5}$, from 2.8 mmol/l to 3.13 mmol/l - $\frac{3,13-x}{3,13-2,8}$, more than 3.13 mmol/l - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$\mu(x_8) = \begin{cases} 0, & \text{if } x \leq 2,5 \\ \frac{x - 2,5}{2,8 - 2,5}, & \text{if } 2,5 < x \leq 2,8 \\ \frac{3,13 - x}{3,13 - 2,8}, & \text{if } 2,8 < x \leq 3,13 \\ 0, & \text{if } x \geq 3,13 \end{cases}$$

A decrease in total serum calcium in cows reveals secondary osteodystrophy disease. **Organic phosphorus (method Pulse by V.F.Kromyslov and modification by L.A. Kudryatsev).** Organic phosphorus in cows $x_9$: up to 1.45 mmol/l - 0, from 1.45 mmol/l to 1.60 mmol/l - $\frac{x-1,45}{1,60-1,45}$, from 1.60 mmol/l to 1.94 mmol/l - $\frac{1,94-x}{1,94-1,60}$, more than 1.94 mmol/l - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$\mu(x_9) = \begin{cases} 0, & \text{if } x \leq 1,45 \\ \frac{x - 1,45}{1,60 - 1,45}, & \text{if } 1,45 < x \leq 1,60 \\ \frac{1,94 - x}{1,94 - 1,60}, & \text{if } 1,60 < x \leq 1,94 \\ 0, & \text{if } x \geq 1,94 \end{cases}$$

A low amount of organic phosphorus in the serum of cows reveals osteodystrophy diseases and secondary osteodystrophy. **Glucose (color reaction with orthotoluidine).** Glucose in the blood of cows $x_{10}$: up to 2.5 mmol/l - 0, from 2.5 mmol/l to 2.7 mmol/l - $\frac{x-2,2}{2,7-2,2}$, from 2.7 mmol/l to 3.3 mmol/l - $\frac{3,3-x}{3,3-2,7}$, more than 3.3 mmol/l - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$\mu(x_{10}) = \begin{cases} 0, & \text{if } x \leq 2,2 \\ \frac{x - 2,2}{2,7 - 2,2}, & \text{if } 2,2 < x \leq 2,7 \\ \frac{3,3 - x}{3,3 - 2,7}, & \text{if } 2,7 < x \leq 3,3 \\ 0, & \text{if } x \geq 3,3 \end{cases}$$
If dairy cows have low blood glucose levels, this indicates ketosis. **Reserve alkali (CO₂) vol% (by the method I.P. Kondrakhin).** Reserve alkali in cows $x_{11}$: up to 44 - 0, from 44 to 55 - $\frac{x-44}{55-44}$, from 55 to 66 mmol / l - $\frac{66-x}{66-55}$ more than 66 - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$
\mu(x_{11}) = \begin{cases} 
0, & \text{if } x \leq 44 \\
\frac{x-44}{55-44}, & \text{if } 44 < x \leq 55 \\
\frac{66-x}{66-55}, & \text{if } 55 < x \leq 66 \\
0, & \text{if } x \geq 66
\end{cases}
$$

If the amount of alkaline reserve in the blood serum of dairy cows is much less than the indicators, then this reveals the disease of secondary acute dystrophy and ketosis. **Copper.** Copper in the blood of cows $x_{12}$: up to 14.1 μmmol / L - 0, from 14.1 μmmol / L to 15.7 μmmol / L - $\frac{x-14.1}{15.7-14.1}$, from 15.7 μmmol / L to 17.3 μmmol / L - $\frac{17.3-x}{17.3-15.7}$, more than 17.3 μmmol / l - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$
\mu(x_{12}) = \begin{cases} 
0, & \text{if } x \leq 14.1 \\
\frac{x-14.1}{15.7-14.1}, & \text{if } 14.1 < x \leq 15.7 \\
\frac{17.3-x}{17.3-15.7}, & \text{if } 15.7 < x \leq 17.3 \\
0, & \text{if } x \geq 17.3
\end{cases}
$$

A decrease in the amount of copper in the blood mmol reveals diseases of osteodystrophy and hypomicroelementosis in dairy cows. **Cobalt mmol / l.** Cobalt in the blood of cows $x_{13}$: up to 0.51 mmol / l - 0, from 0.51 mmol / l to 0.68 mmol / l - $\frac{x-0.51}{0.68-0.51}$, from 0.68 mmol / L to 0.85 mmol / L - $\frac{0.85-x}{0.85-0.68}$, more than 0.85 mmol / l - 0. Confidence in belonging to $\mu(x)$ is described by the expression:
A decrease in the amount of cobalt by 12% in the blood of cows leads to the disease of osteodystrophy and hypomicroelementosis.

**Manganese mmol / l. Manganese in the blood of cows** $x_{14}$: up to 2.73 mmol / l - 0, from 2.73 mmol / l to 3.64 mmol / l - $\frac{x-2.73}{3.64-2.73}$, from 3.64 mmol / l to 4.55 mmol / l - $\frac{4.55-x}{4.55-3.64}$, more than 4.55 mmol / l - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$
\mu(x_{14}) = \begin{cases} 
0, & \text{if } x \leq 2.73 \\
\frac{x-2.73}{3.64-2.73}, & \text{if } 2.73 < x \leq 3.64 \\
\frac{4.55-x}{4.55-3.64}, & \text{if } 3.64 < x \leq 4.55 \\
0, & \text{if } x \geq 4.55 
\end{cases}
$$

A decrease in the amount of manganese in the blood of cows leads to the disease of osteodystrophy and hypomicroelementosis.

**Zinc mmol / l. Zinc in the blood of cows** $x_{15}$: up to 46.2 mmol / l - 0, from 46.2 mmol / l to 61.6 mmol / l - $\frac{x-46.2}{61.6-46.2}$, from 61.6 mmol / l to 77.0 mmol / l - $\frac{77.0-x}{77.0-61.6}$, more than 77.0 mmol / l - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$
\mu(x_{15}) = \begin{cases} 
0, & \text{if } x \leq 46.2 \\
\frac{x-46.2}{61.6-46.2}, & \text{if } 46.2 < x \leq 61.6 \\
\frac{77.0-x}{77.0-61.6}, & \text{if } 61.6 < x \leq 77.0 \\
0, & \text{if } x \geq 77.0 
\end{cases}
$$

A decrease in the amount of zinc by 25-33% in the blood leads to the disease of osteodystrophy and hypomicroelementosis in cows.
4.3 Factors of scar content
The number of infusoria in the rumen 1000 / ml. The number of infusoria in the rumen 1000 / ml in cows $x_{16}$: to 552 - 0, from 552 to 595 - $\frac{x-552}{595-552}$, 595 to 638 - $\frac{638-x}{638-595}$, more than 638 – 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$\mu(x_{16}) = \begin{cases} 
0, & \text{if } x \leq 552 \\
\frac{x-552}{595-552}, & \text{if } 552 < x \leq 595 \\
\frac{638-x}{638-595}, & \text{if } 595 < x \leq 638 \\
0, & \text{if } x \geq 638 
\end{cases}$$

A decrease in the number of ciliates in the rumen by 300 ± 45 leads to ketosis and hypomicroelementosis in cows.

The condition of the cicatricial fluid (with the RAMeter). The condition of the rumen fluid in cows $x_{17}$: up to 6.5 - 0, from 6.5 to 7 - $\frac{x-6.5}{7-6.5}$, from 7 to 7.5 mmol / l - $\frac{7.5-x}{7.5-7}$, more than 7.5 - 0. Confidence in belonging to $\mu(x)$ is described by the expression:

$$\mu(x_{17}) = \begin{cases} 
0, & \text{if } x \leq 6.5 \\
\frac{x-6.5}{7-6.5}, & \text{if } 6.5 < x \leq 7 \\
\frac{7.5-x}{7.5-7}, & \text{if } 7 < x \leq 7.5 \\
0, & \text{if } x \geq 7.5 
\end{cases}$$

A decrease in the condition of the scar fluid does not lead to ketosis disease and secondary osteodystrophy in cows.

Conclusion
The results showed the high efficiency of the proposed decision-making algorithm for forecasting, classification and measurement of poorly formalized processes described by fuzzy models [5]. The etiology of secondary osteodystrophy, osteodystrophy, ketosis and hypomicroelementosis through the use of a predictive model in veterinary practice allows to optimize veterinary and sanitary work in the Samarkand region. The available knowledge about the existing experimental data makes it possible to improve the adequacy of the fuzzy expert system.

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