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Determination of Milk Production from Cattle using Fuzzy Expert Model

Rachna Navalakhe[1] and Arshi Sheikh[2]
[1]Assistant Professor, [2]Student of Masters of Science
Department of Applied Mathematics and Computational Science
Shri G.S. Institute of Technology and Science, Indore (M.P.)
sgsits.rachna@gmail.com, arshi.sheikh02@gmail.com

ABSTRACT

The study has been conducted to analyze the production of milk from livestock using fuzzy expert system. Livestock means farm animals considered as an asset. India consists of a large amount of livestock resources such as milk. Fuzzy logic can be used to manage uncertainty in expert systems and solve problems that cannot be solved effectively by conventional methods. The main aim of fuzzy expert systems is to use human knowledge to process uncertain and ambiguous data. The objective of this paper is to implement a fuzzy logic expert system which will help to determine the suitable conditions required for the improved and increased production of milk from livestock.

Keywords: Livestock; Fuzzy logic; Milk production**.**

1. INTRODUCTION

The word 'Livestock' was first used between 1650 and 1660 and derived from the two words "live" and "stock". Earlier, the word "Cattle" and "Livestock" have been used interchangeably. Today, livestock is used in a wider sense. Livestock serves two thirds of the rural community. It also provides employment to about 8.8 % of India's population. India consists of a large amount of livestock resources. Among livestock, cattle are the largest animal population in the country whose population is about 192.90 million adding to the total livestock population which is about 535.78 million. Livestock systems surround 30% of the planet's terrestrial area and are a remarkable asset to living beings (Steinfeld et al. 2006). The livestock systems have both positive and negative effects on the natural resource, public health, social equity and economic growth (World Bank, 2009). The livestock sector is well organized in long market chains that give employment to millions of people globally and it also supports the livelihood of millions of small scale farmers in developing countries (Thornton, 2006).

The leading producer of milk in the world is India, so the country's share in world milk production stands at 17%. The production and consumption of milk is the highest in India. There is a high demand for consumption of milk and dairy products in the consumer market. Therefore, quality and quantity control becomes mandatory (Martini, 2018). According to the current reports and statistics provided by The Department of Animal Husbandry and Dairying (DAHD), (2020-21), an all-time high milk production of 209 million tonnes was recorded, which is more than half of which produced from cattle. A decision support system is developed on dairy cows' monthly milk yield by using the fuzzy logic method (Strasser, 2016). Various input variations are studied for the fuzzy logic decision support system (Wade et al. 1998). The productivity of Indian cows is very low (Sethumadhavan, 2017). Therefore, to increase the productivity of milk proper measures must be taken for various input factors

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such as breeding, hygienic management, feeding. The dairy industry plays a vital role in rural development (Nargunde, 2013). An average growth of milk production in India has increased since 1970 and the country became the largest milk producer in the world in 2006 (Muhammad et al. 2009).

2. CONCEPT OF FUZZY LOGIC

Lotfi Zadeh, the father of fuzzy Logic created the idea of fuzzy logic at the University of California at Berkeley in the 1960s. Fuzzy logic is an approach to variable processing that allows for multiple possible truth values to be proposed through the same variable. The truth value of variables may be any real number between 0 and 1 which are interpreted as degrees of truth. It represents uncertainty and the belongingness of a member of a crisp set to fuzzy set. Membership function works on fuzzy sets of variables. Fuzziness is characterized by its membership function. If X is a universe of discourse and x ϵ X then a fuzzy set A in X is defined as a set of ordered pairs such that

$A = \{(x, \mu_A(x)) \mid x \epsilon X\}$

where,

$\mu_A(x)$ = Membership function for fuzzy set A

2.1 Triangular membership function

It is defined by three parameters {a, b, c}, where ∀x, the membership function $\mu_{triangle}(x)$ is described as:

$$\mu_{triangle}(x; a, b, c) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{cases}$$

2.2 Trapezoidal membership function

It is defined by four parameters {a, b, c, d}, where
∀x, the membership function $\mu_{trapezoidal}(x; a, b, c, d)$ is described as:

$$\mu_{trapezoidal}(x; a, b, c, d) = \begin{cases} 0, & x \le a \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ \frac{d-x}{d-c}, & c \le x \le d \\ 0, & d \le x \end{cases}$$

2.3 Architecture of fuzzy logic system

Fuzzy logic architecture has four main parts:

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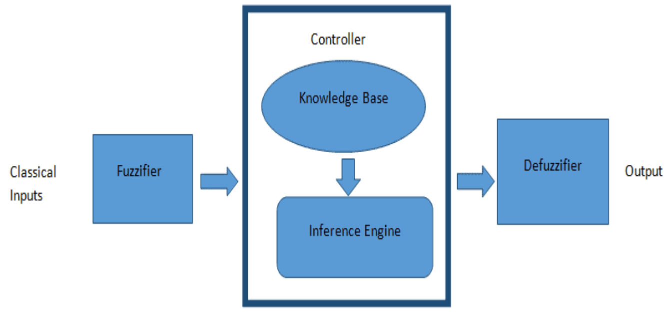

Fig.1 Fuzzy Inference System

3. FUZZY LOGIC BASED EXPERT SYSTEM FOR MILK PRODUCTION

This fuzzy expert system is designed on the basis of knowledge to solve certain problems in this field. This is the best suited method when a user provides data which is vague and incomplete. This work illustrates a fuzzy approach to calculate the productivity of milk. The system uses fuzzy logic to map the given inputs to an output, i.e., productivity of milk.

In this proposed work, a fuzzy logic system has been developed to calculate the productivity of milk. The system accepts six input parameters, i.e., Temperature, Feed, Age, Protein, Energy and Water and provides the output of production of milk. The range of input and output variables have been decided by expert opinions. Firstly, linguistic variables are defined for input parameters and their membership functions are calculated. Afterwards, fuzzy rules are created. This is done with the help of MATLAB using a fuzzy toolbox.

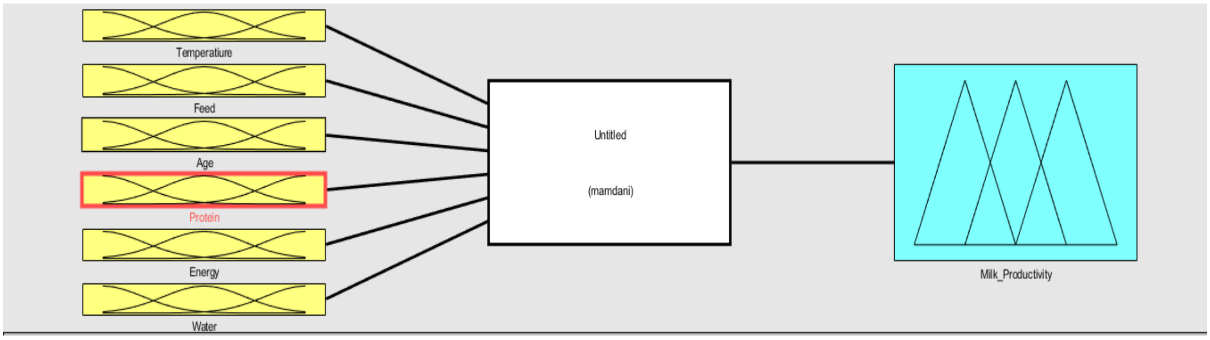

Fig.2 Structure of fuzzy inference system with six inputs and one output

3.1 Proposed Algorithm

Step 1	Start
Step 2	Input the values of various factors into the fuzzy logic system and its range of output i.e., production of milk.
Step 3	Convert the input and output values into linguistic terms.
Step 4	Construct the membership functions for each linguistic term.
Step 5	Construct the IF- THEN rules according to the experts.

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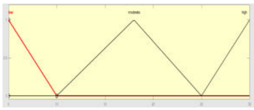
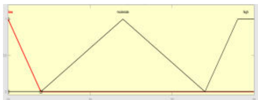
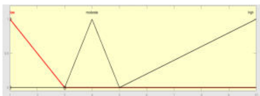
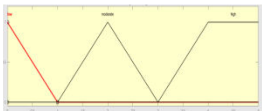
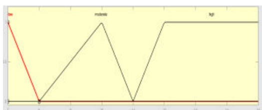
Step 6	Check the rules for getting a higher productivity percentage of milk with the help of MATLAB.
Step 7	Determine the rule base evaluation.
Step 8	Compute the output of milk production.
Step 9	Stop

Table 1: Input Parameters Included for Milk Production

Production of Milk				Membership Function
Factors	Linguistic Variables			
Input Variables	Low	Moderate	High	
Temperature (°C)	≤ 10	10 – 25	≥ 25	 Membership Function for Temperature
Feed (Kg)	≤ 12	12 – 22	≥ 22	 Membership Function for Feed
Age (Years)	≤ 3	3 – 5	≥ 5	 Membership Function for Age
Protein (Pounds)	≤ 1	1 – 3	≥ 3	 Membership Function for Protein
Energy (Mcal)	≤ 8	8 – 11	≥ 11	 Membership Function for Energy

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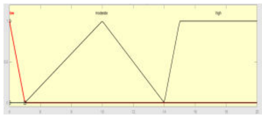
Water (Gallons)	≤ 5	$5 - 14$	≥ 14	 Membership Function for Water

Membership functions for Temperature

Low	Moderate	High
$\mu_L(x) = \begin{cases} 0, & x \geq 10 \\ \dfrac{10-x}{5}, & 5 < x < 10 \end{cases}$	$\mu_M(x) = \begin{cases} 0, & (x \leq 10,\ x \geq 25) \\ \dfrac{x-10}{8}, & 10 < x \leq 18 \\ \dfrac{10-x}{7}, & 18 < x < 25 \end{cases}$	$\mu_H(x) = \begin{cases} 0, & x \leq 25 \\ \dfrac{x-25}{5}, & 25 < x < 30 \end{cases}$

Membership functions for Feed

Low	Moderate	High
$\mu_L(x) = \begin{cases} 0, & x \geq 12 \\ \dfrac{12-x}{2}, & 10 < x < 12 \end{cases}$	$\mu_M(x) = \begin{cases} 0, & (x \leq 12,\ x \geq 22) \\ \dfrac{x-12}{5}, & 12 < x \leq 17 \\ \dfrac{22-x}{5}, & 17 < x < 22 \end{cases}$	$\mu_H(x) = \begin{cases} 0, & x \leq 22 \\ \dfrac{x-22}{2}, & 22 < x \leq 24 \\ 1, & 24 < x < 25 \end{cases}$

Membership functions for Age

Low	Moderate	High
$\mu_L(x) = \begin{cases} 0, & x \geq 3 \\ \dfrac{3-x}{2}, & 1 < x < 3 \end{cases}$	$\mu_M(x) = \begin{cases} 0, & (x \leq 3,\ x \geq 5) \\ \dfrac{x-3}{1}, & 3 < x \leq 4 \\ \dfrac{5-x}{1}, & 4 < x < 5 \end{cases}$	$\mu_H(x) = \begin{cases} 0, & x \leq 5 \\ \dfrac{x-5}{5}, & 5 < x \leq 10 \end{cases}$

Membership functions for Protein

Low	Moderate	High

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$\mu_L(x) = \begin{cases} 0, & x \geq 1 \\ \frac{1-x}{1}, & 0<x<1 \end{cases}$	$\mu_M(x) = \begin{cases} 0, & (x \leq 1,\ x \geq 3) \\ \frac{x-1}{1}, & 1<x \leq 2 \\ \frac{3-x}{1}, & 2<x<3 \end{cases}$	$\mu_H(x) = \begin{cases} 0, & x \leq 3 \\ \frac{x-3}{1}, & 3<x<4 \\ 1, & 4 \leq x \leq 5 \end{cases}$

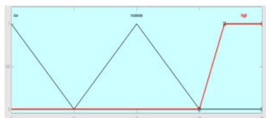
Membership functions for Energy

Low	Moderate	High
$\mu_L(x) = \begin{cases} 0, & x \geq 8 \\ \frac{8-x}{1}, & 7<x<8 \end{cases}$	$\mu_M(x) = \begin{cases} 0, & (x \leq 8,\ x \geq 11) \\ \frac{x-8}{2}, & 8<x \leq 10 \\ \frac{11-x}{1}, & 10<x<11 \end{cases}$	$\mu_H(x) = \begin{cases} 0, & x \leq 11 \\ \frac{x-11}{1}, & 11<x<12 \\ 1, & 12 \leq x \leq 15 \end{cases}$

Membership functions for Water

Low	Moderate	High
$\mu_L(x) = \begin{cases} 0, & x \geq 5 \\ \frac{4-x}{1}, & 4<x<5 \end{cases}$	$\mu_M(x) = \begin{cases} 0, & (x \leq 5,\ x \geq 14) \\ \frac{x-5}{5}, & 5<x \leq 10 \\ \frac{14-x}{4}, & 10<x<14 \end{cases}$	$\mu_H(x) = \begin{cases} 0, & x \leq 14 \\ \frac{x-14}{1}, & 14<x<15 \\ 1, & 15 \leq x \leq 20 \end{cases}$

Table 2: Output Parameter for Milk Production

Production Of Milk				Membership Function
Production	Linguistic Variable			
Output Variable	Low	Moderate	High	
Productivity (%)	≤ 10	10 – 20	≥ 20	

Membership functions for Milk Productivity

Low	Moderate	High

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$\mu_L(x) = \begin{cases} 0, & x \geq 10 \\ \dfrac{10-x}{5}, & 5 < x < 10 \end{cases}$	$\mu_M(x) = \begin{cases} 0, & (x \leq 10,\ x \geq 20) \\ \dfrac{x-10}{5}, & 10 < x \leq 15 \\ \dfrac{20-x}{5}, & 15 < x < 20 \end{cases}$	$\mu_H(x) = \begin{cases} 0, & x \leq 20 \\ \dfrac{x-20}{2}, & 20 < x < 22 \\ 1, & 22 \leq x \leq 25 \end{cases}$

3.2 Fuzzy Rules for Inference

1. If (Temperatiure is moderate) and (Feed is moderate) and (Age is low) and (Protein is moderate) and (Energy is high) and (Water is high) then (Milk_Productivity is high) (1)
2. If (Temperatiure is low) and (Feed is moderate) and (Age is moderate) and (Protein is moderate) and (Energy is moderate) and (Water is high) then (Milk_Productivity is moderate) (1)
3. If (Temperatiure is high) and (Feed is high) and (Age is low) and (Protein is moderate) and (Energy is moderate) and (Water is high) then (Milk_Productivity is moderate) (1)
4. If (Temperatiure is moderate) and (Feed is low) and (Age is high) and (Protein is low) and (Energy is low) and (Water is low) then (Milk_Productivity is low) (1)
5. If (Temperatiure is low) and (Feed is low) and (Age is high) and (Protein is low) and (Energy is low) and (Water is low) then (Milk_Productivity is low) (1)
6. If (Temperatiure is moderate) and (Feed is moderate) and (Age is high) and (Protein is low) and (Energy is moderate) and (Water is high) then (Milk_Productivity is moderate) (1)
7. If (Temperatiure is high) and (Feed is moderate) and (Age is low) and (Protein is high) and (Energy is high) and (Water is high) then (Milk_Productivity is high) (1)
8. If (Temperatiure is low) and (Feed is low) and (Age is low) and (Protein is moderate) and (Energy is moderate) and (Water is low) then (Milk_Productivity is low) (1)
9. If (Temperatiure is moderate) and (Feed is low) and (Age is low) and (Protein is high) and (Energy is low) and (Water is moderate) then (Milk_Productivity is moderate) (1)
10. If (Temperatiure is high) and (Feed is high) and (Age is moderate) and (Protein is high) and (Energy is high) and (Water is high) then (Milk_Productivity is high) (1)
11. If (Temperatiure is low) and (Feed is high) and (Age is low) and (Protein is high) and (Energy is high) and (Water is low) then (Milk_Productivity is moderate) (1)
12. If (Temperatiure is high) and (Feed is high) and (Age is high) and (Protein is low) and (Energy is low) and (Water is moderate) then (Milk_Productivity is low) (1)
13. If (Temperatiure is moderate) and (Feed is moderate) and (Age is moderate) and (Protein is moderate) and (Energy is high) and (Water is high) then (Milk_Productivity is high) (1)

Fig 3. Rule Base System

3.3 Variations in Productivity

The below table shows the variation in percentage of productivity of milk on changing the parameters involved in the production of milk.

CASE	TEMPERATURE (°C)	FEED (Kg)	AGE (Years)	PROTEIN (Pounds)	ENERGY (Mcal)	WATER (Gallons)	PRODUCTIVITY (%)
I	6.43	11	9.49	0.283	7.32	4.49	6.89
II	6.86	11.1	6.41	0.5	7.25	4.63	7.12
III	11	10.9	9.57	5	7.67	4.49	7.29
IV	19.6	13.8	4.51	1.93	13.9	16.3	22.7
V	26.2	23.2	1.91	1.93	9.84	18	15
VI	7.08	10.6	8.54	0.326	7.53	4.21	6.92
VII	28.6	14.4	2.7	3.11	11.7	15.4	22.6
VIII	27.5	23	8.14	0.674	7.11	11.4	7.07
IX	16.5	15.9	3.64	2.2	11.8	14.7	22.9
X	6.86	11	8.93	0.5	7.39	4.63	7.02

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XI	18.2	17.5	4.17	2.5	11.6	15.2	22.8
XII	29.2	24.1	1.67	1.76	9.63	14.6	15.3
XIII	15	11.1	2.14	3.8	7.67	11.6	14.9

From the above table, the highest productivity percentage is (22.9%), moderate productivity percentage is (15.3%) and low productivity percentage is (6.89%).

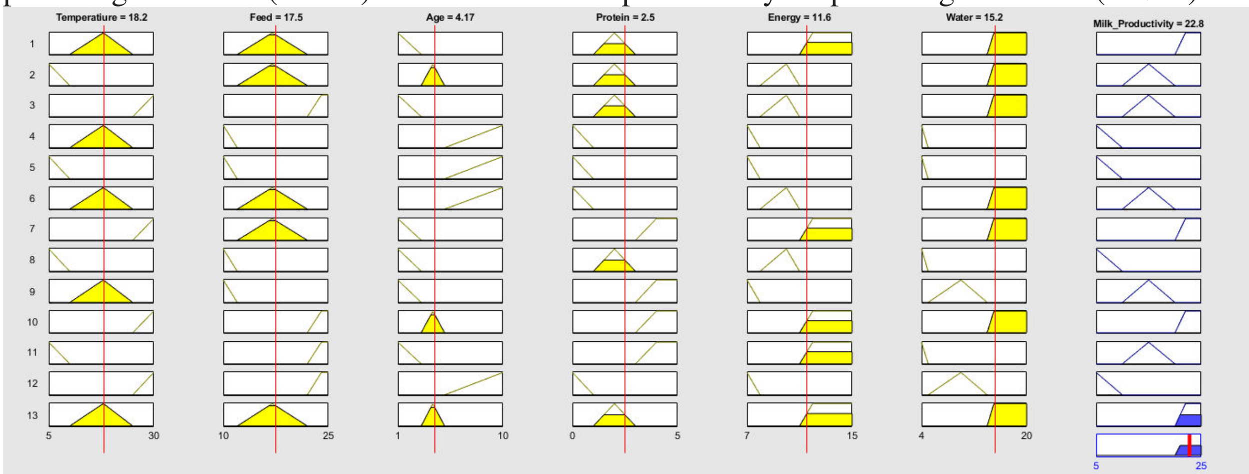

Fig.4 Rule evaluation of highest productivity percentage

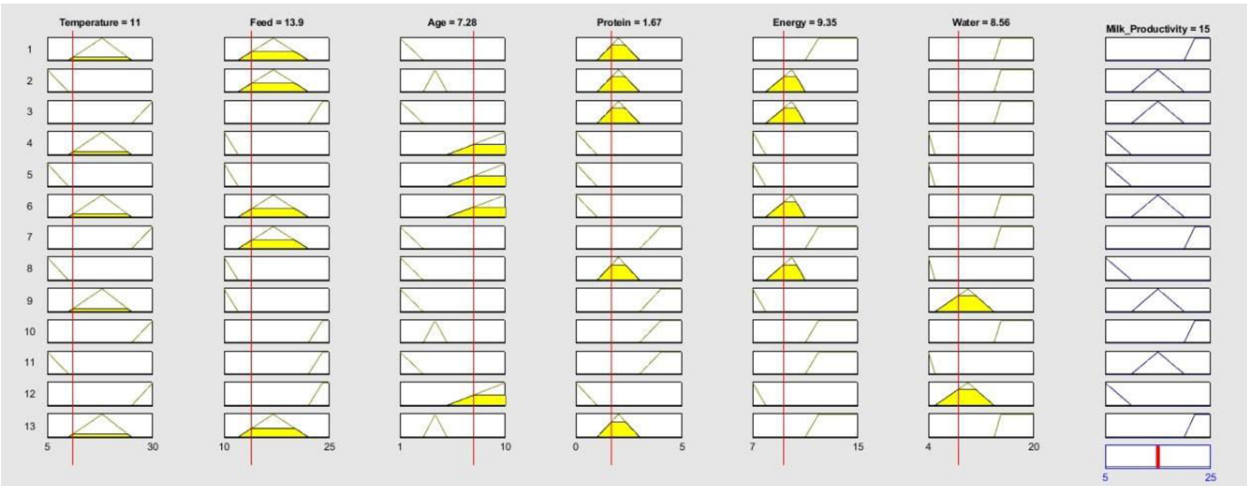

Fig.5 Rule evaluation of moderate productivity percentage

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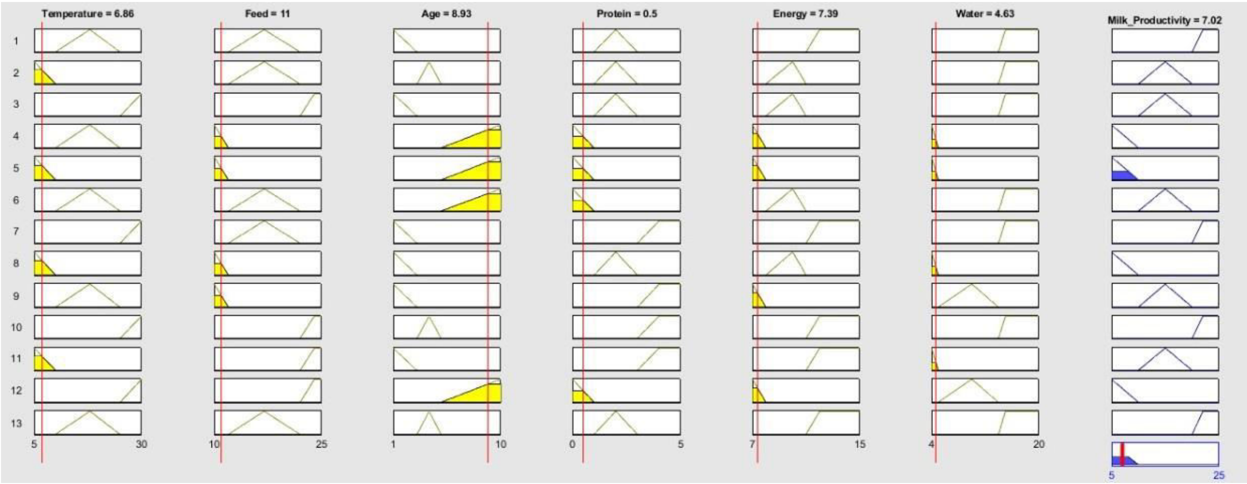

Fig.6 Rule evaluation of lowest productivity percentage

CONCLUSION

In this work, a fuzzy logic based expert system has been developed to increase the production of milk in India. The defined factors and their given ranges are considered as input and the productivity of milk is considered as the output. Afterwards, the IF-THEN rules are constructed. Later, this system is tested and evaluated with the help of experts to assure the needs of the system. If a proper scientific method is used and precautions are taken regarding the quantity of feed, nutrition, water, etc., higher yield of milk can be produced. This work also contains data in tabulated form which shows variation in productivity of milk when the values of temperature, feed, age, nutrients and water are changed. It is observed that if all these factors are used in correct proportion and under suitable weather conditions, the production of milk is highest.

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