Romanian Biotechnological Letters *Vol. 19, No.6, 2014*

ORIGINAL PAPER

Scientific research based on innovative bioeconomy for the computer optimization of fodder rations in zootechnic

Received for publication, April 15, 2014
Accepted, October 20, 2014

IOAN SURDU[1], GEORGE FLOREA TOBĂ[2]
[1]S.C. SIAT S.A.- Informatical Systems for Automation Bucharest, Calea Floreasca no. 169, postcode 014459, sector 1, Bucharest, Romania
[2]Romanian Academy, INCE, Center for Studies and Researchers Agroforestry Biodiversity, Bucharest, ROMÂNIA
** Address correspondence to: Informatical Systems for Automation Bucharest, Calea Floreasca no. 169, postcode 014459, sector 1, Bucharest, Romania;*
Mobile: +40.0727.368.054, E-mail: surdu.ioan@gmail.com

Abstract

This work presents a synthesis of the scientific research performed by the authors for over 10 years, including the Postdoctoral School of the last three years, regarding bio-economy applied in animal husbandry for the efficient and durable development of fodder resources specific to certain geographic areas. The scientific research and experiments carried out along time proved that the quantity and quality of animal productions can significantly be influenced by nutrition. Bio-economy applied in the formulation and computer optimization of fodder rations, regarding the economic aspect as well as quantity and quality of nutrient content, differentiated per species, breeds, categories of age and production, physiological status and, mainly, on the specificity of animal productions, was based on the results of scientific research of nutrition physiology performed in metabolic chambers, computer assisted stands for the study of the cattle nutritional behaviour (ZOOTRON) and on mathematical models of simulation of the energetic and protein metabolism, developed by the authors under the coordination of Gheorghe Burlacu, Ph.D. Rations for dairy cows weighing between 500-700 kg and milk production between 5000 - 9000 kg/lactation were formulated and optimized using the computer application PERFORMNUT For swine, the CARSUIN software application was developed , which was used in order to formulate and optimize combined feed recipes for growing and fattening pigs with body weights between 30 -120 kg and daily weight gain between 0.500 - 1.000 kg.

Keywords*:* innovative bioeconomy ; metabolic energy; fodder rations.

1. Introduction

Determination of optimal and balanced dietary nutrition for dairy cows is a complex process that requires the integration of a large volume of data and information. A dairy cow ration's conception and evaluation, by elaborating a software application, refers to creating applicative modules (M. Vermorel, Coulon J.B., 1992 [13]) that are acting as:

- Defining a nutritional data base
- Evaluation of nutritional characteristics for ingredients contained in dairy cows feed rations
- Calculating the dairy cows nutritional requirements
- Formulation and evaluation on a feed ration

The PERFORMNUT software application is an important logistical support to consequently develop basic research and also an efficient tool for nutritionists and farmers, in order to improve the use of fodder for dairy cows and achieve desired growth and milk production as well as improve bio-economic performance (Bogdan A. T. et all,

2012[2][3][4][5][6]). The nutritional software PERFORMNUT, created in a team effort with specialists from SIAT Bucharest and National Institute for Research and Development in animal husbandry Balotesti, represents the reference element to create a useful simplified nutritional instrument for farmers.

2. Materials and methods

This research aimed at elaborating and developing scientifically sustained methods and instruments for calculus and formulation of nutritional dairy cows diets, in order to ensure nutrient requirements for obtaining an increase of weight, milk production and bio-economic efficiency (price cost). (Agnew R.E., and Yan T., 2000 [1])

In order to fulfil the above mentioned functions, the nutritional software includes 3 modules:

- a module for evaluation of nutritional values in feedstuffs (Burlacu Gh. et all 2002[7])
- a module for calculus of nutritional requirements
- a module for conception, optimization and estimation of diet efficiency

The first module, which refers to the evaluation of nutritional values in dairy cows feeding, contains a data base with specific items for nutritional metabolism of dairy cows (Burlacu Gh. et all 1998 reprint in 2002 [8][9][10] [12]). Feedstuffs are divided on multiple levels, generally noted as: Group, Subgroup, Type, Subtype, Product, By-product.

The main nutrients considered in order to evaluate nutritional values of dairy cows (N.R.C. 2001[15]) feeding are: brute energy, total proteins, total nitrogen, total fats, total carbohydrates, cellulose, vitamin A, beta-carotenes, vitamin D, vitamin E, sodium, potassium, calcium, phosphor, iron, copper, zinc, iodine, manganese, selenium, lysine and methionine. The data base includes two parts: a references basis, including standard values for products with established values, given by the reference feedstuffs, and a user basis, with complete access regarding adding or correcting data given by the lab tests. The number of considered nutrients is high enough to permit a hypothesis formulation and a fair analysis towards studied effects. (Burlacu Gh. et all 2002 [11])

Energy, protein, essential amino-acid, vitamins, macro and microelements requirements are calculated for all dairy cow body functions, including: maintenance, physical activities, body weight gain, milk production depending on number of lactation, week of lactation, body weight.

The basic equation for calculus of feed rations for dairy cows.

From mathematical point of view the optimization problem is expressed by the following relationship:

$$\sum_{i=1}^{P} x_i \le SUI_{\max} \quad (1.1)$$

$i = \overline{1, p}$ - number of fodder in ration

$$\sum_{i=1}^{\varphi} X_i \cdot \mathrm{ENL_i} \ge \mathrm{A_{nec}/E} \quad (1.2)$$

$$\sum_{i=1}^{P} X_i \cdot PDIN_i \ge PDI_{nec} \quad (1.3.)$$

$$\sum_{i=1}^{P} X_i \cdot \mathrm{PDIE_i} \ge \mathrm{PDI_{nec}} \quad (1.4)$$

$$\sum_{j=1}^{P} X_i \cdot AAdig_{ij} \ge AAdig_{nec,j} \quad (1.5)$$

$j = \overline{1, q}$ q – nr. AA optimized limiters

$$\sum_{i=1}^{P} X_i \cdot Min_{ik} \ge Min_{nec,k} \quad (1.6)$$

$k = \overline{1, r}$ r – nr. Optimized macro elements and minerals

$$\sum_{i=1}^{P} X_i \cdot Vit_{iq} \ge Vit_{nec,q} \quad (1.7)$$

$q = \overline{1, v}$ v – nr. Optimized vitamins

$$X_i \ge 0 \quad \forall i = \overline{1, p} \quad (1.8)$$

$\mathrm{ENL_i}$ = milk net energy content of the fodder "i"
$\mathrm{PDIN_i}$ = intestinal digestible protein allowed by nitrogen content of the fodder "i"
$\mathrm{PDIE_i}$ = intestinal digestible protein allowed by energy content of the fodder "i"
$\mathrm{AAdig_{ij}}$ = amino-acid "j" content of the fodder "i"
$\mathrm{Min_{ik}}$ = macro-element "k" content of the fodder "i"
$\mathrm{Vit_{iq}}$ = vitamin "q" content of the fodder "i"

Because a part of the parameters are expressed by nonlinear functions, in order to optimize the feed rations, specific optimization methods and algorithms are required applying piecewise linearization techniques for analyzed curves.

Depending on the purpose, a highly accurate prediction is required for the respective productive group and for each individual. In cases of diagnosis, the significant differences between the individual prediction curves and the real ones or between parts of the curves will point out aspects of the inadequate nutrition aspects or illness.

A good model is adequate both for managerial purposes, and for diagnosis. The current surveys allowed the development of lactation prediction patterns by highlighting the individual variability used both for managerial purpose, and for diagnosis.

In the practical applications, the empirical method is by far more efficient for predicting the lactation curve for diary cows.

Among the equations obtained by different authors, a good estimation is offered by the expression used within the English system (AFRC, 1993[14]) :

$$Pl = e^{a-0,5tli(1+0,39tli)-0,86/ti} \quad \text{[kg/day]} \quad (1.9)$$

where: a = productive parameter;

$$tli = (ti - 150)/100 \quad (1.10)$$

ti = no. of postpartum days

As current estimators of the lactation curve, the real productive data measured individually for each dairy cow is used which enables the calculation of daily milk production at the beginning of the lactation Pl_{IL} and the maximum daily production for the whole lactation cycle Pl_M, respectively,.

Pl_{IL} is calculated as an average milk production obtained in the lactation days 4, 5 and 6, and it is given by the expression:

$$Pl_{IL} = (Pl_4 + Pl_5 + Pl_6) / 3 \quad (1.11)$$

where Pl_i is the real milk production milked on day *i*.

Having the Pl_{IL} values measured, the value of parameter *a* is calculated, and its value is used as an estimator of milk daily production in the following days, given by the equation:

$$a = \ln Pl_{IL} - 0.1387 \quad (1.12)$$

With value *a* calculated, the milk production in the lactation day "i" can be estimated, which allows the calculation of the food ratio for the milk production of the given day.

In figure 1.1. the evolution curves of daily milk production for dairy cows with productions between 4000-8000 kg of milk per lactation cycle are presented.

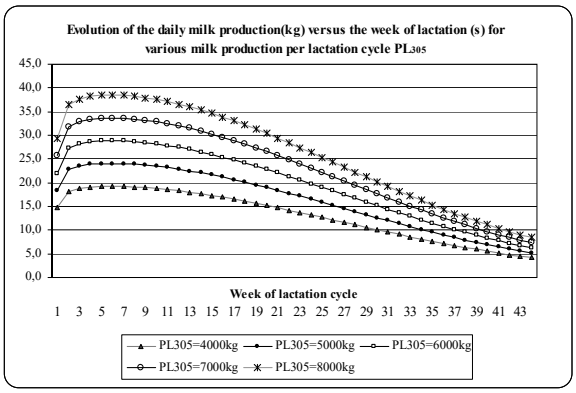

Fig. 1.1. Evolution of the daily milk production during the lactation cycle

Data analysis showed that for dairy cows the milk production increases rapidly at the beginning of lactation, reaching the maximum value during the 5th lactation week. Production is kept at a maximum value up to the 20th week after which there is a continuous decrease until the end of lactation. A dynamic correction of the lactation curve for each dairy cow in the herd can be made by measuring the real daily milk production. The presented curves may constitute references for most of dairy cow breeds in our country whose production levels are generally between 4000-6500 kg of milk per lactation cycle.

For the correct estimation of feed rations, in case a real weighting of the animals is not performed, it is necessary to elaborate a simulation pattern.

This pattern has to be corrected periodically by measuring the real weight of dairy cows.

As an estimator of body weight for the whole lactation cycle the following expression was used:

$$G(s, Pl_M) = G_f \cdot \left[1 + a \cdot Pl_M \cdot \left(b \cdot \ln s + c \cdot s + d \cdot s^2 + e \cdot s^3 + f / s + g\right)\right] \text{ [kg]} \quad (1.13)$$

where:

G_f = weight at calving;
Pl_M = maximum daily milk production;
s = lactation week
a, b, c, d, e, f and g = parameters that, within the pattern, have the following values:
a = 0.0001; b = 13.435; c = -0.4617; d = -0.0168; e = -0.00005;

From the analysis of data regarding the evolution of body weight for multiparous dairy cows with mature body weight between 550 - 700 kg and a maximum daily milk production per lactation cycle between 20-40 kg, it was ascertained that dairy cows mobilize body reserves in the first 10 weeks of lactation. The body mobilization on lactation cycle depends on the body weight of the diary cow and on the daily maximum milk production

For a dairy cow characterized by milk production on the lactation cycle PL_{305} and mature body weight G_{mat} it is estimated a weight variation on the "i" lactation day, which allows the correction of the feed ration for changing the body weight coresponding to that day.

$$\Delta G = [G(s+1)-G(s)]/7 \quad \text{[kg]} \quad (1.14)$$

The prediction of the maximum ingestion of dry substance by dairy cows is a very important parameter in formulating and optimizing feed rations.

The pattern drawn-up and used in this work estimates SUI_{max} with the expression:

$$SUI_{max} = 0.21 \times Pl_{cor} + 0.011 \times G + s^{0,64} \times e^{-0,03s+0,98/s+0,82} \text{ [kg]} \quad (1.15)$$

where:

Pl_{cor} = milk production corrected with the fat percentage;
G = animal's weight in the current lactation week;
s = lactation week;

In figure 1.2. the evolution curves of the maximum consumption of dry substance for multiparous dairy cows with mature body weight between 500-700 kg and a milk production on lactation cycle of 6000 kg are presented.

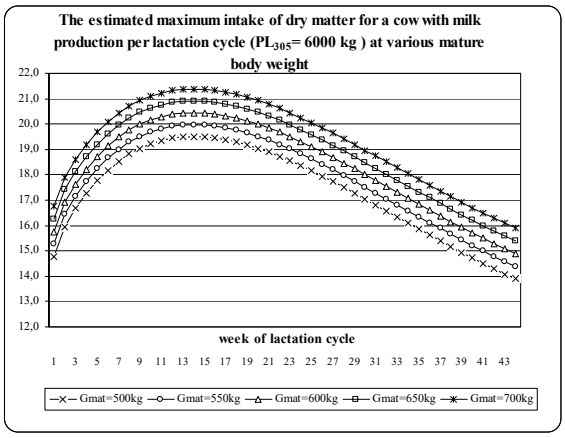

Fig. 1.2. The estimated maximum dry matter intake according to mature cow weight

In figure 1.3. the evolution curves of the maximum consumption of dry substance for multiparous dairy cows with mature body weight of 600 kg and milk productions between 4000-8000 kg of milk per lactation cycle are presented.

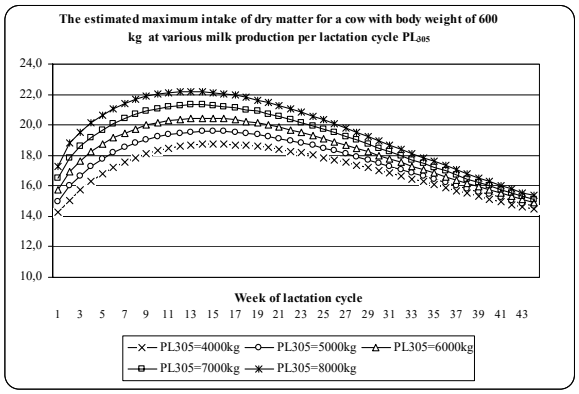

Fig. 1.3. The estimated maximum dry matter intake according to milk production per lactation cycle

The analysis of diagrams 1.2. and 1.3. shows that immediately after calving,, dairy cows may achieve a consumption of dry substance of almost 75-85% of the maximum value, to which they arrive during weeks 10-16 of lactation. After reaching the plateau value, the ingestion capacity progressively decreases while milk production decreases, reaching a level of 80-85% of the maximum value at the end of lactation.

During the 5-6 lactation weeks when milk production reaches the maximum value, the consumption of dry substance reaches almost 90% of the ingestion maximum capacity. This temporary gap between milk production and consumption of dry substance determines the elaboration of specific feeding strategies in high performance dairy cows i.e. the use of very good quality forage, with a high protein and energetic value at the beginning of lactation.

The dynamic pattern used for optimizing the feed rations permanently performs the energetic corrections for estimating the nutritional requirement, considering the reserve mobilization/the weight gain estimated for the whole lactation cycle. By optimizing the food ratios, depending on energetic contributions necessary for each productive group during the

whole lactation cycle, the estimated milk production can be provided, i.e. a variation of body weight as close as possible to the ideal one.

The methodologies drawn up and developed are complex and they contain aspects regarding the survey and elaboration of scientific support materialized in components of the nutrition system of farm animals.

The calculation methodologies and the techniques used align the formulation and optimizing procedures of food rates intended for dairy cows to the modern feeding principles developed in countries with an advanced animal husbandry within the European Union.

The software modules are written with MICROSOFT VISUAL C [16], they have a dynamic character and promote the development as a user application.

3. Results and comments

The nutritional software PERFORMNUT is an application written with MICROSOFT VISUAL C and uses Windows specific tools and controls. PERFORMNUT includes seven menus: File, Edit, Tools, View, Window and Help. File, Edit, View and Window comprise submenus, with standard Windows associated functions and commands. Tools menu has several submenus used to select a particular window and specific commands to elaborate file proceedings on nutrient requirements, diet formulation and evaluation; Help menu contains the interactive on-line manual.

The module for calculus of nutritional requirements is carried out as a necessary evaluation screen (energy, protein, etc.), based on an individual description. It is realized with tab controls, including a tab for user requirements generated by the model. Model calculations are based on energy, protein, dry matter and macro-elements requirements.

For dairy cows, the model contains information about body weight, gestation, lactation, and environment. The module for formulation, optimization and estimation of the feed ration efficiency includes two screens.

In the first screen, the user sets their daily rations, possibly in three forms. This offers a list for: basic ration, mixed ration and complement production. For dairy cows mixed rations are usually used (consisting of forages and concentrate feed) covering production requirements for each productive category.

Mixed rations and rations obtained by supplementing basic rations with production complement should cover the daily requirements for each productive category of dairy cows in gestation and/or lactation.

The second screen operates many data, especially the ration, computed as mentioned above, and the nutritional requirements. It solves a lot of tasks, it computes especially the ration efficiency and shows how the proposed ration is able to comply with nutritional requirements.

4. Conclusions

The software application PERFORMNUT presents a scientific and practical utility. It allows the nutritional characterization from various points of view (energy, protein, amino-acids, fat, macroelements) and takes into consideration the metabolism of dry and lactating cows.

The application uses two databases for ingredients, all having the same structure. One database is completely for the user and contains ingredients especially for that user. Ingredient categories and new ingredients can be added within this database and any values of

characteristics can be modified.

The nutritional requirements can be estimated for various dairy cows category, according to the weight, environment, housing, physical activity, they are dependent on the desired economic performance (body weight gain, milk quality, milk production).

Using the PERFORMNUT computer application rations for dairy cows with body weights between 500-700 kg, and milk production on lactation between 5000 - 9000 kg in elite farms as well as with milk production on lactation between 3500 - 6500 kg in household farms were formulated and optimized.

PERFORMNUT Nutritional software is an application intended to be used by nutrition specialists and dairy farmers in order to formulate economically and balanced rations for dry and dairy cows.

A nutritional software application called CARSUIN was developed for swine which was used for the formulation and optimization of combined feed recipes for growing and fattening pigs with body weights between 30 -120 kg and daily weight gain between 0.500 - 1.000 kg.

References

1. AGNEW R.E., AND YAN T., 2000. *Impact of recent research on energy feeding systems for dairy cattle.* Livestock Production Science. 66: 197-215.
2. BOGDAN A. T. et all, 2013, *Compared bio-economy postdoctoral research for agrifood bio-security, Economic Publishing House* , ISBN 978- 973 -709 - 656 – 2.
3. BOGDAN A. T. et all, 2012, *Biodiversity of farm animals and eco-bio-economics significances in the food security context,* The Publishing House of Romanian Academy, ISBN 978- 973 -27 - 2183 – 4.
4. BOGDAN A. T. et all (The second edition- revised and supplemented), 2012, Eco-bi-economic solution based on agroforestry biodiversity to provide the sustainable agrifood independence of european and euro-atlantic Romania, Libris Danubiu Publishing House , ISBN 978- 606 - 928 – 29 – 0 - 8.
5. BOGDAN A. T., D. L. DIACONESCU, STRATEANU AMALIA-GIANINA, CHELMU S., SURDU I., M. TH. PARASCHIVESCU, *Solutions for zootechnical crisis by assuring agri-food independence and sovereignty of European-Romania*, Intervention in the debate on the topic: What can we learn from the current economic crisis?, Aula Magna of Romanian Academy, Bucharest, 14th April 2009, Romanian Academy Publishing House, ISBN 978-973-27-1802-5.
6. BOGDAN A. T., B. PASARIN, CHELMU S., STRATEANU AMALIA, SURDU I., M. TH. PARASCHIVESCU *"Positioning of animal sciences based on the original concept regarding to the priority development of Eoropean-Romania as agri-food green power* – Prezentation at theNational Symposium "Modern animal husbandry – Science, creativity and innovation", USAMV Iasi, 9th-10th April 2009, Romanian Academy Publishing House, Bucharest, ISBN 978-973-27-1800-1.
7. BURLACU GH., R. BURLACU, A. CAVACHE, I. SURDU, (2002), Productive potential of feeds and their use, CERES Publishing House, Bucharest, Romania, I.S.B.N.: 973-40-0541-3.
8. BURLACU GH., I. SURDU, R. BURLACU, A. CAVACHE, (1998 reprint in 2002), *Indicators of the new system to assess the nutritional value of feeds for ruminants*, published by Minister of Agriculture and Food, National Agency for Agricultural Consulting, O.J.C.A. Constanţa, Romania, I.S.B.N.: 973-8036-00-3.
9. BURLACU GH., I. SURDU, R. BURLACU, A. CAVACHE, (1998 reprint in 2002), *Guide to formulate food rations for growing and fattening young cattles*, published by Minister of Agriculture and Food, National Agency for Agricultural Consulting, O.J.C.A. Constanţa, Romania, I.S.B.N.: 973-8036-00-3.
10. BURLACU GH., I. SURDU, R. BURLACU, A. CAVACHE, (1998 reprint 2002), *Guide to formulate food rations for dairy cows*, , published by Minister of Agriculture and Food, National Agency for Agricultural Consulting, O.J.C.A. Constanţa, Romania, I.S.B.N.: 973-8036-00-3.
11. BURLACU GH., I. SURDU, R. BURLACU, A. CAVACHE, (2002),), Guide to formulate food rations for cattle, published by General Association of Cattle Breeders from Romania, I.S.B.N.: 973-8036-00-3Burlacu Gh., 1985, Energy metabolism in farm animals, Ed. Ceres,

Bucureşti.Faverdin P., Baumont R., Ingvarsen K.L., 1995. Control and prediction of feed intake in ruminants. IVth Symposium Nutrition Herbivore, 95 -114.

12. INGVARTSEN K. L., 1994. *Models of voluntary food intake in cattle*. Livestock Production Science, 39: 19-38
13. M. VERMOREL, COULON J.B., 1992. *Comparaison des systèmes d'alimentation enérgétique.* Productions Animales, 5, (4), 289-298.
14. A.F.R.C., 1993. *Energy and protein requirements of ruminants.* An advisory manual prepared by the AFRC Technical Committee on responses to nutrients. CAB International, Wallingford, U.K.
15. N.R.C., 2001. *Nutrient Requirements of Dairy Cattle.* Seventh Revised Edition, National Academy Press, Washington D.C**.**
16. MICROSOFT VISUAL STUDIO – Developing for Windows and Web.