

BCBCM

The Beef Cattle Body Composition Model to Predict the Composition of Growing Cattle

(Modelo de Composição Corporal de Gado de Corte)

History, Science, and User Guide

Version 2.0.1, revision 3

Luis Orlindo Tedeschi

https://www.nutritionmodels.com

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About this document

Copyright. © 1997–2027 Luis Orlindo Tedeschi. All rights reserved. This document comes with the BCBCM program and may be copied and distributed with it.

Disclosure. This document was written with support from an artificial intelligence assistant (a chatbot) and from Dr. Tedeschi's papers, dissertation, and programs, and Dr. Tedeschi reviewed it and is responsible for its content.

Language. The program works in English and in Portuguese (menu *Tools > Language*). This document shows the screens and uses the names of the menus, windows, and fields in English, set in italics; the Portuguese version does the same in Portuguese. The screens were made using the MCCGC sample database (MCCGC.MDB), which BCBCM opens as-is; its four animals are those of BCBCM.MDB, but with their names in Portuguese (*à pasto*, on pasture; *em terminação*, in the feedlot); BCBCM.MDB, which the setup installs, names them in English.

Conflict of interest. BCBCM is available at https://www.nutritionmodels.com. Its registration fees are kept to the minimum needed to maintain the program and to host the website. Dr. Tedeschi declares no other conflict of interest.

Funding and development. BCBCM, and MCCGC before it, were developed by Dr. Tedeschi, beginning in 1997 at ESALQ/USP. He wrote their code himself, on computers and with software he acquired for the purpose, including the growth models of the library Growth.dll that BCBCM shares with his other programs: the Williams model, the growth model of CVDS, the Cattle Value Discovery System (Tedeschi et al., 2004), and the model of the University of California, Davis (Oltjen et al., 1986a; Oltjen et al., 1986b). No external funds supported their programming. He held teaching and research positions in ruminant nutrition; he wrote the programs on his own time. Like all his models, this program's roots go back to his undergraduate years at ESALQ/USP, where courses in linear programming, operations research, animal nutrition, and statistics met his passion for computers, and some of the code he wrote then found its way into his programs. He also self-funded his studies.

Disclaimer. The U.S. Department of Agriculture (USDA), its Agricultural Research Service (ARS), and the U.S. Meat Animal Research Center (MARC) did not fund any part of the development of MCCGC or BCBCM. The messages of Dr. Charles B. Williams quoted in section 1.1 are personal scientific correspondence, reproduced for the historical record; they do not represent the views or the policies of the USDA, and they are not an endorsement or an approval of MCCGC or BCBCM by the USDA or by any of its agencies. Neither the University of São Paulo, Cornell University, nor Texas A&M University funded the writing of the MCCGC or BCBCM code.

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About the author. Luis Orlindo Tedeschi is Professor of Ruminant Nutrition in the Department of Animal Science at Texas A&M University, where he has worked since 2005, and Honorary Professor at the University of Sassari, Italy. He is an Agronomic Engineer from the *Escola Superior de Agricultura "Luiz de Queiroz"* of the University of São Paulo (ESALQ/USP, 1991), where he also earned his M.S. (1996), and he earned his Ph.D. in Animal Science at Cornell University in 2001, staying there as a postdoctoral fellow and research associate until 2005. His research focuses on ruminant nutrition, including energy and nutrient supply and requirements in cattle, sheep, and goats, and it has been cited more than 19,000 times. He is a Fellow of the American Society of Animal Science and was a Fulbright scholar. He learned to program at ESALQ's Centro de Informática na Agricultura (CIAGRI), where, from 1988, he took courses in Pascal, structured BASIC, Lotus 1-2-3, dBase, and SAS and, as an undergraduate intern, helped other users with theirs. He reads, speaks, and writes Portuguese and English, gets along in Spanish, and has since added Visual Basic, R, Python, and Mathematica to the list, which he mostly uses at night and on weekends. He firmly believes every model is wrong, and equally firmly hopes his are useful.

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List of Acronyms

ARS = Agricultural Research Service; BCBCM = Beef Cattle Body Composition Model; CIAGRI = *Centro de Informática na Agricultura*; CNCPS = Cornell Net Carbohydrate and Protein System; CVDS = Cattle Value Discovery System; DECI = Decision Evaluator for the Cattle Industry; EBW = empty body weight, kg; ESALQ = *Escola Superior de Agricultura "Luiz de Queiroz"*; FFM = fat-free matter, kg; MARC = U.S. Meat Animal Research Center; MBCSM = MARC Beef Cattle Systems Model; MCCGC = *Modelo de Composição Corporal de Gado de Corte*; NEg = net energy for gain, Mcal/day; NEm = net energy for maintenance, Mcal/day; NRC = National Research Council; USDA = U.S. Department of Agriculture; USP = *Universidade de São Paulo* (University of São Paulo).

Abstract

This document is the history, science, and user guide for the Beef Cattle Body Composition Model (BCBCM), version 2.0.1, a Windows program, in English and Portuguese, that predicts the body composition of growing cattle (empty body weight, fat-free matter, and fat) from their growth and plane of nutrition. Its model is the postweaning model of the MARC Beef Cattle Systems Model (Keele et al., 1992; Williams, 1995), which divides empty body weight into fat-free matter and fat and follows both through time, with a lagged response to changes in nutrition that helps explain compensatory growth. The first chapter traces the program from the FORTRAN code Charles B. Williams sent in 1995, through MCCGC, written at ESALQ/USP in 1997, to BCBCM, quoting the correspondence of 1995–2004. The second describes the model, its assumptions and parameters, and how to calculate net energy for maintenance and gain. The third is a user guide to every window of the program, and the fourth works through the example of Hereford and Charolais steers on pasture and in the feedlot. Revision 2 (October 30, 2026) follows the herd model Williams announced in 1997 as the Decision Evaluator for the Cattle Industry (DECI). The project began in 1995 at the National Cattlemen's Association, was developed by USDA-ARS from 1996, and released versions 1.0 in 1998 and 2.0 in 1999 (Hardin, 1998; Dunn et al., 1999). Revision 2 also adds a List of Acronyms, cites sources as live references, makes every web address a link, and rewrites the user guide in plainer language. The window pictures (Figures 1 to 9) were taken again on November 9, 2026, with the register number grayed out for privacy. Revision 3 (November 20, 2026) describes the new *Tools > Logs* menu, which turns the error log and the start-up reports on or off, shows the license number in the pictures of the splash screen and the About window (Figures 1 and 9), adds this abstract, a section on what to do when something goes wrong, and a missing reference, and edits the text for clarity.

1. How the program began

BCBCM (Beef Cattle Body Composition Model) is the name that **MCCGC**, *Modelo de Composição Corporal de Gado de Corte*, received in 2026, in version 2.0.1, when it began to work in English as well. The program is the same, and its history, told in this section, is MCCGC's history, the name under which it appears here. MCCGC was conceived to answer a recurrent question in beef cattle production: why can animals of the same live weight carry such different amounts of body fat?

The program originates in Dr. Tedeschi's Master's dissertation, defended in 1996 at the *Escola Superior de Agricultura "Luiz de Queiroz"* (**ESALQ**), University of São Paulo, on the growth curves of Guzerá cattle and their crossbreds raised on pasture with and without supplementation (Tedeschi, 1996; Tedeschi et al., 1999; Tedeschi et al., 2000a; Tedeschi et al., 2000b; Tedeschi et al., 2002). In that work, nonlinear functions were fitted to animal weights from birth to maturity to summarize growth in a few biologically interpretable parameters: mature weight, maturing rate, and an integration parameter associated with birth weight.

That study sparked interest in the body composition of growing cattle. In 1997, Dr. Tedeschi wrote the essay "*Algumas considerações sobre crescimento e composição de bovinos de corte*" (Some considerations on the growth and composition of beef cattle), in which growth curves were used to discuss the degree of maturity, defined as the ratio of current weight to mature weight. That essay's conclusion became the program's central premise: animals of different mature sizes do not have the same body composition at the same weight because they are at different degrees of maturity, and animals with a higher maturing rate deposit more fat at the same age.

The basis for quantifying that composition was the pair of papers by Keele et al. (1992) and Williams et al. (1992), from the Roman L. Hruska U.S. Meat Animal Research Center (**MARC**; **USDA**, Clay Center, Nebraska), already cited in the dissertation (Tedeschi, 1996). These papers describe a dynamic model, formulated in differential equations, that predicts how nutrition levels change the composition of empty body gain, and evaluate it using data from eight experiments. Dr. Williams's group had programmed that model in FORTRAN, as **MBCSM**, the MARC Beef Cattle Systems Model (Williams, 1995), and sent the program to Dr. Tedeschi in April 1995 (section 1.1). The author translated it into QBASIC and then into Visual Basic; the result is MCCGC, *Modelo de Composição Corporal de Gado de Corte*, whose first version dates from October 1997. The original purpose was to evaluate the effect of the periods of feed restriction and realimentation, that is, compensatory growth, to which cattle raised on pasture are subjected until slaughter weight. Elements of MCCGC were later incorporated into the growth model of **CVDS**, the Cattle Value Discovery System (Tedeschi, 2026; Tedeschi and Fox, 2020a, b; Tedeschi et al., 2004).

The sample database distributed with the program includes four cases from the example data file that Charles B. Williams, one of the model's authors, sent with the code in April 1995 (section 1.1): Hereford and Charolais steers, each raised on pasture and in the feedlot. The structure of that example, constant gain to weaning followed by a quadratic weight curve in the feedlot in both accelerated and conventional systems, matches the simulations of Williams and Bennett (1995). The values follow those of the steers of that center's germplasm evaluation program (Williams et al., 1995a): the *theta* of 6.3 for the Hereford and the initial and weaning empty body weights of the Charolais (38.2 and 193 kg) appear in the tables of that paper, whereas the mature weights and the *theta* of 7.8 for the Charolais were not published; the four cases are

in the file of 1995. In the database, the note for each animal records the origin: “Dados originais do exemplo de Charles B. Williams em MBCSM - Marc Beef Cattle Systems Model - User’s Guide” (original data of the example of Charles B. Williams in the User's Guide of the MBCSM; Williams, 1995). Section 4 presents the simulation of these four cases.

The 1992 model continued to be developed at the same center. Williams et al. (1995a, 1995b, 1995c) estimated its parameters for 17 biological types of cattle and simulated postweaning production systems; Williams and Jenkins (1997, 1998) extended it to mature cattle and to all stages of maturity; and the model became the core of **DECI**, the Decision Evaluator for the Cattle Industry (Jenkins and Williams, 1998), whose model of metabolizable energy utilization was described by Williams and Jenkins (2003a, 2003b, 2003c). DECI and CVDS were compared in predicting feed intake and feed efficiency of steers (Williams, 2010; Williams et al., 2006), with minimal differences between the two (Tedeschi et al., 2006a; Tedeschi et al., 2006b).

Since then, the program’s core has remained the same. In 2001, the equations were transferred to an independent library (Growth.dll), which MCCGC calls to perform the calculations. The library gathers more than one growth model: the Williams model, used by MCCGC; the growth model of CVDS (Tedeschi et al., 2004), which incorporated elements of MCCGC (Tedeschi and Fox, 2020a, b); and the Davis growth model (Oltjen et al., 1986a; Oltjen et al., 1986b). Each program calls the corresponding model. The versions from 2019 to 2026 (1.0.32 to 1.1.5) updated the setup, the graphs, and the presentation of the results, and version 2.0.1, the first under the name BCBCM, introduced English, the graphs in free windows, the figures drawn by R, the new splash screen, the start-up checks, the error log, this document, and the new licensing.

1.1 The correspondence with Charles B. Williams (1995–2004)

Dr. Tedeschi’s files contain electronic correspondence with Charles B. Williams of the Meat Animal Research Center from 1995 to 2004. They document where the code, parameters, and sample animals of MCCGC came from. The messages are quoted below; the time is the writer’s local time (Clay Center, Nebraska; Piracicaba, São Paulo; or Ithaca, New York). Williams’s replies are as sent, with the few typing slips corrected; Luis Tedeschi’s messages, written in the beginner’s English of the time, received small corrections of grammar, and each word added or replaced is given in square brackets, in upright type. It is presented in two parts: the early exchanges, from the request for the model to the program (1995–1997), and the later exchanges, from Cornell (1997–2004), in which Dr. Tedeschi and Williams traded models, papers, and results.

Early exchanges (1995–1997)

Early in 1995, still a Master’s student, Luis Tedeschi wrote to Williams asking for the model of Keele et al. (1992). That first message was not preserved (the copies of his sent messages that survive begin in December 1995); the reply was. On April 6, 1995, Williams sent, in the body of a message, the FORTRAN code of MBCSM, the MARC Beef Cattle Systems Model (Williams, 1995): the program, the parameter file, with *Kmax* 0.916, *Kmin* 0.12, and *Klag* 0.03, and a data file with four example animals, Hereford (604 kg, *theta* 6.3) and Charolais steers (757 kg, *theta* 7.8), each on pasture and in the feedlot. Those four animals are, to this day, the sample database of MCCGC, and those three values are the standard parameters of the program.

> **CHARLES B. WILLIAMS, CLAY CENTER, NEBRASKA, APRIL 6, 1995, 9:18 AM**
>
> *"Sorry for the long delay in replying. I had to leave off and do some other things. I am sending your four files named MBCSM.FOR, MBCSM.INC, MBCSM.IN, and MBCSM.DAT. You need to compile the fortran file on your system. The users manual is almost complete and I will mail you a copy by surface mail next week. It may take about two weeks to get there. Best of luck, in case of problems you could contact me by* e-mail*, and please feel free to do so.*
>
> *Sincerely, Charles B. Williams"*

Luis Tedeschi translated the FORTRAN program into QBASIC. The remark that opened that translation, "*programa para estimativa de %Gordura, desenvolvido por Charles Williams, modificado por Luis Orlindo Tedeschi*" (program to estimate the percentage of fat, developed by Charles Williams, modified by Luis Orlindo Tedeschi), is still the first line of the main module of MCCGC. In November and December 1995, Williams answered questions about how to estimate *theta* and which values should not be changed.

> **CHARLES B. WILLIAMS, NOVEMBER 30, 1995, 3:06 PM**
>
> *"I am enclosing a paper on how I estimated TETA values. You first need an estimate of the standard reference weight (SREBW), and body composition data and growth rates. Then vary TETA until you can predict the observed composition using the observed growth rates. For Zebu type cattle you could try 720 kg for SREBW. Kmax and Kmin are constants for all breeds and must not be changed. You could start with a value of 6 for TETA and if the simulated composition at slaughter is fatter than the observed, use a larger value for TETA, and if it is leaner use a smaller value for TETA."*
>
> **CHARLES B. WILLIAMS, DECEMBER 1, 1995, 3:27 PM**
>
> *"The KLAG value of 0.03 is a constant and should not be changed. […] Finally I suggest that the best way may be to start all your simulations at birth with 3% fat, since this is a good estimate and you could grow the animals up to the point at which you have experimental data on weights."*

In June 1996, with the doctorate at Cornell already planned and data from two experiments with Nellore steers under feed restriction, Dr. Tedeschi wrote again to ask how to obtain the model's energy requirements.

> **LUIS O. TEDESCHI, PIRACICABA, JUNE 6, 1996, 10:54 AM**
>
> *"Hi Dr. Williams, I am so glad to talk* [to] *you again. I am not sure if you remember me, but some time ago I had talked* [to] *you about the MARC model and you sent it to me. I had asked some questions about how to estimate TETA and KMAX parameters. […] We* [need] *the information* [on] *where and how* [to] *include that routine to estimate MEg (gain) and MEm (maintenance),* [as] *you* [described] *in that paper."*
>
> **CHARLES B. WILLIAMS, JUNE 11, 1996, 2:34 PM**
>
> *"The model predicts fat-free matter (FFM) and FAT. FFM contains protein, water and ash, but only protein has energy. You can estimate the amount of protein in FFM as FFM*0.243. Then retained energy (RE) = PROTEIN * 5.7 + FAT * 9.5. […] The subroutine DAILY can be used. In this subroutine you can do these calculations on a daily basis and accumulate the results over the feeding period."*

That reply is the origin of the calculation of the net energy for gain in MCCGC and of the three parameters of the *Growth* tab of the *Parameters* window (*Crescimento* and *Configuração* in MCCGC): the proportion of protein in the fat-free matter (0.243) and the gross energies of protein and fat (5.72 and 9.5 Mcal/kg). In the next exchange, Dr. Tedeschi asked about the review of Owens et al. (1993), the 720 kg suggested for Zebu cattle, and the use of the National Research Council (NRC, 1984) equation for maintenance with the factor 0.89, which the program uses to this day.

> **CHARLES B. WILLIAMS, JUNE 17, 1996, 12:09 PM**
>
> *"The response in fat accretion to growth rate is highly variable, and is dependent to a large extent on previous nutrition. Our model simulates these responses when compared to experimental data. The biggest difference we get is when animals at the same age, weight and composition are fed to grow at different rates, then the animals that grow the slowest are the leanest when compared with the faster growing animals at the same weight. EBW at 25 % is an estimate of a weight and composition which animals are trying to achieve. We call it a standard reference EBW, and it works well in defining a target EBW and composition. […] 720 kg is for Zebu steers. Using 0.89 with NRC equation seems to okay for Nellore cattle, but I can only be certain if I had some data to work with."*

In September 1996, Dr. Tedeschi reported the fit of the model to the Nellore steers, with a mature empty body weight of 575 kg and a *theta* of 5.63, the values that the validation written in 1997 kept.

> **LUIS O. TEDESCHI, PIRACICABA, SEPTEMBER 17, 1996, 11:32 AM**
>
> *"Mr. Williams, I used your model to simulate* [the] *growth and composition* [of some Nellore data]. *Well, first I calculated mature EBW using CSIRO and* [your] *values, then I estimated* [theta] [so as to minimize] *the differences between observed and estimated fat composition at* [the desired] *weights. I used 575 for mature EBW and 5.63 for* [theta]*; those values worked fine with animals without feed restriction. […] I insist, I do not believe that 720* [kg] *for mature EBW (Nellore steers) is an adequate value; I think this value is* [too high]*."*
>
> **CHARLES B. WILLIAMS, SEPTEMBER 26, 1996, 8:31 AM**
>
> *"I have not finished preparing the updated model as yet, I am busy working on another project, but as soon it is done I will send the files to you. I would like to take a look at that Nellore data and do some work with the model on it."*

In May 1997, three months before leaving for Cornell, Luis Tedeschi wrote that he had written a program using the model code: MCCGC, whose first Visual Basic files date from October of that year. The model had already run outside FORTRAN and QBASIC: a spreadsheet Dr. Tedeschi created on September 29, 1996, twelve days after the message on the fit to the Nellore steers, reproduces the Williams model in Excel. The oldest version of the program that was kept complete is 1.0.25, of January 2000, written in Visual Basic 4 and identified as "MCCGC for Windows 95/98"; its splash screen reads "Copyright © 1996".

> **LUIS O. TEDESCHI, PIRACICABA, MAY 7, 1997, 4:56 PM**
>
> *"I am sending this* e-mail *just to ask you if you* [have] *finished the model modifications. I* [have written] *a* [program] *using your* [code], *and it is working very* [well]. *I used it to simulate* [the] *Nellore growth (*[as] *I told you before)* [and] *it fits perfectly."*
>
> **CHARLES B. WILLIAMS, MAY 8, 1997, 1:06 PM**
>
> *"Thank you for the note on what you have done. I am glad that the model has worked in some way. Since we last corresponded, a lot has happened. We now have a full herd model in which there is a cow/calf model and the postweaning model. Also I have built a user interface for data input and output analysis. I will be demonstrating this model at the animal science meeting in Nashville, Tenn, on Thursday, 31st of July."*
>
> **CHARLES B. WILLIAMS, MAY 12, 1997, 8:01 AM**
>
> *"The full program will be available in September. For the post weaning phase the code is the same as what I sent to you. However we have added on a cow/calf component and are completing a user interface. There are a few papers that are coming and I will send them to you."*

Later exchanges (1997–2004)

The correspondence went on from Cornell. On October 7, 1997, three days after the date of the first files of MCCGC, Williams wrote to Luis Tedeschi, who had just arrived in Ithaca; in 1999 he sent him the model

on a CD; in 2001, when Dr. Tedeschi was preparing the addition of a growth model to the Cornell Net Carbohydrate and Protein System (**CNCPS**), he pointed him to DECI; and in 2002, the year the growth model of CVDS was taking shape, he asked for the papers of that system. In 2003 and 2004, the exchange turned to the use of the two models, DECI and the growth model of CVDS, to predict feed intake and feed efficiency.

> **CHARLES B. WILLIAMS, OCTOBER 7, 1997, 8:39 AM**
>
> *"It is nice that you are finally starting out on your Ph.D program. Dante did visit MARC and we talked about the model, it would be good for you to come to MARC for a visit. [...] We have done a lot of work with the model and I will send you some papers soon. We have developed a graphical user interface to enter input and run the model. This system will be tested in December and we will have ready to go in January 1998."*
>
> **LUIS O. TEDESCHI, ITHACA, NOVEMBER 21, 1999**
>
> *"I am re-opening my research in animal composition, and I remember you told me at Denver you were working on a new model to improve the prediction when protein was deficient in the diet. Have you changed your model? Where may I find the latest version for evaluation?"*
>
> **CHARLES B. WILLIAMS, NOVEMBER 22, 1999, 2:11 PM**
>
> *"I will send you a CD with the model today. The one on the WEB is out of date."*
>
> **LUIS O. TEDESCHI, ITHACA, FEBRUARY 14, 2001, 10:42 AM**
>
> *"We are currently updating the CNCPS model and probably we will add a growth model* [to] *it. I would like to know if you have any new version of your growth model and if that limitation of restricted intake of protein has been addressed. Also, how do I get the latest copy of DECI?"*
>
> **CHARLES B. WILLIAMS, FEBRUARY 15, 2001**
>
> *"The most up to date version of DECI can be downloaded from our web site [...]. The model is driven by energy intake and we have not included any response to protein nutrition. We have just completed a User's Guide in PDF format for DECI."*
>
> **LUIS O. TEDESCHI, ITHACA, SEPTEMBER 10, 2002, 3:57 PM**
>
> *"Hi Charles, attached* [are] *the BIF papers and the CNC paper regarding the CVDS model. I am working on a growth model and feed efficiency evaluation that is the kernel of the CVDS; as soon as I have it done, I will send it to you for your appreciation."*
>
> **CHARLES B. WILLIAMS, SEPTEMBER 10, 2002**
>
> *"At the moment I am extracting out the code for the feedlot model from DECI to make an independent feedlot model. [...] You mentioned in Quebec that the CNCPS was being reprogrammed in Visual Basic. I work with Visual Basic and it may be easier for me to use the Visual Basic code, than try to recode equations. [...] At present the feedlot part is working with energy, and I now need to start incorporating protein."*
>
> **CHARLES B. WILLIAMS, JUNE 30, 2003**
>
> *"Anyway the point I was trying to make was that when you adjust the value of kg to account for* [composition] *of gain, the concept of a feed having a single NEg value becomes invalid. [...] Also I would like the equations used to calculate the required intake so that I can begin work on evaluating predicted EPDs for efficiency with CNCPS and DECI."*
>
> **LUIS O. TEDESCHI, ITHACA, JUNE 30, 2003, 8:36 PM**
>
> *"Agree with you that a common NEg is required because of the nature of the adjustment; that is exactly what we do in the CVDS since it uses one dietary ME value. The CNCPS 5.0 is done."*

> **CHARLES B. WILLIAMS, MARCH 12, 2004**
>
> *"I have 502 individual feed intake records on steers including growth and carcass data. I have used my model to predict the required feed intake and would like to use the system developed at* [Cornell] *to do the same. […] If changes have been made could you send me a set of equations."*
>
> **LUIS O. TEDESCHI, ITHACA, MARCH 13, 2004, 11:27 AM**
>
> *"Attached is the pdf file of the manuscript published in the Agricultural* [Systems] *journal. I have also developed a computer program that uses that set of equations to estimate DM required given an animal's performance."*

The herd model Williams announced in 1997 became DECI, the Decision Evaluator for the Cattle Industry (Jenkins and Williams, 1998). The project began in 1995 in the Integrated Resource Management subcommittee of the National Cattlemen's Association, which brought together producers, extension specialists, and scientists; USDA-**ARS** took on its development in May 1996, updating an existing animal production model; the alpha version was evaluated at Clay Center in April 1997, version 1.0 was released at the 1998 annual meeting of the National Cattlemen's Beef Association, and version 2.0, of 1999, added the postweaning enterprises of backgrounding, stocking, and finishing (Dunn et al., 1999). Williams, who developed much of the energy model, brought that work into the DECI project led by Thomas G. Jenkins, and from January 1998 the new version for Windows 95 was made available to other researchers (Hardin, 1998). The postweaning phase, as he wrote in 1997 and again in 2002, remained that of the code sent in 1995, and it is that phase that MCCGC simulates; and the growth model Dr. Tedeschi said he was writing in 2002 is that of CVDS (Tedeschi et al., 2004), which incorporated elements of MCCGC. Dr. Tedeschi's files keep DECI and its manual (MARC, 2000) as they were obtained on February 17, 2001, two days after the message in which Williams pointed to them. The paper sent in March 2004 is the one that describes the growth model of CVDS (Tedeschi et al., 2004). The comparison Williams was then preparing, of observed feed intake with the intake predicted by DECI and by the Cornell model, was published two years later (Williams et al., 2006), and he returned to the subject later (Williams, 2010).

2. The science behind the model

The BCBCM model is the postweaning model of MBCSM (Keele et al., 1992; Williams, 1995). It divides empty body weight (**EBW**) into two compartments, fat-free matter and fat, and tracks both over time. Empty body gain (kg/day) is the variable that represents the level of nutrition: animals of the same genotype gaining weight at different rates are on different planes of nutrition.

According to Keele et al. (1992), the model rests on four assumptions:

1. as animals mature, the proportion of fat is greater in the gain than in the body weight;
2. the effects of plane of nutrition on body composition that are not associated with empty body weight are predictable from the rate of empty body gain;
3. the effects of a change in nutrition are not exerted immediately, nor are they permanent;
4. when empty body gain is zero, cattle approach an equilibrium body composition.

Six parameters characterize the model: the fat-free matter of the mature animal; the rate at which composition approaches equilibrium; the minimum and maximum fractional growth rates of fat-free matter relative to that of empty body weight (*Kmin* and *Kmax* in the program); the time constant of the response to a change in nutrition (*Klag*, or *Lambda*); and the fattening parameter (*Theta*), which modulates the influence of degree of maturity and nutrition. Two of them, mature fat-free matter and *theta*, are specific to genotype and sex. In the program, instead of mature fat-free matter, the mature empty body weight (*Mature EBW*) is entered for each animal, defined as the empty body weight of the animal at 25.1% fat (Keele et al., 1992), from which it is obtained as 0.749 of the mature EBW (Williams et al., 1995a); and *theta*.

The lagged response is a distinctive feature of the model. An abrupt change in weight gain does not immediately change the composition of the gain: the model maintains a "lagged gain" that gradually converges to the new rate. This mechanism is what makes it possible to explain the sometimes contradictory results of compensatory growth experiments.

In the model evaluation by Williams et al. (1992), simulated fatness agreed with observed fatness, except for animals fed protein-deficient diets, which grew more slowly and became fatter than their contemporaries, whereas the model predicted the opposite. In the four experiments in which nutritional treatments differed in fatness after accounting for empty body weight, the model explained 13.8 to 56.2% of that variation. With the same model, Williams et al. (1995b) showed that compensating steers may reach slaughter leaner than, as fat as, or fatter than steers finished immediately after weaning: the larger the fraction of the final weight gained during the restriction, the leaner the carcass.

The program integrates the differential equations numerically, step by step, and reports the composition at the points the user requests. For each point, it also computes the net energy for maintenance (**NEm**) and the net energy for gain (**NEg**) using the procedure Williams described to Dr. Tedeschi in 1996 (section 1.1).

3. User guide

BCBCM operates on a database (an .MDB file) that stores the animals, their growth periods, and their output points. The usual workflow is: open or create a database, register the animal, enter its growth periods, and run the simulation.

3.1 Start

At start-up, the program shows the version, license, and notice, and runs five checks (the program and the computer, the data folder, the program files, the components, and whether a newer version exists). The last line shows how they went; clicking it opens the report, which is saved in Documents\NutritionModels\BCBCM Files\Logs. *Tools > Logs* turns the error log and the start-up reports on or off (both are on unless turned off) and opens the Logs folder, the last start-up report, and the error log. Click anywhere else, or press a key, to close the screen (Figure 1).

The database used last opens automatically, and its name appears in the main window title.

Language. At first launch, the program uses the display language of Windows. *Tools > Language* changes between *Português* and *English* at any time, and the choice is remembered.

Registration. BCBCM must be registered, and registration requires a license; an MCCGC registration is not valid. License types and prices are on the Purchase page of https://www.nutritionmodels.com, and the Register page requests the registration code and license number. Without a registration, the program can be started 10 times as an evaluation copy.

Files of MCCGC. BCBCM replaces MCCGC. The first time it starts with no database in use, and there are databases in Documents\NutritionModels\MCCGC Files or parameters changed in MCCGC, it asks once whether to copy them to BCBCM Files. The files are copied, never moved, and never overwrite a file of the same name.

3.2 *File*

In the *File* menu, *Open* lets you choose an existing database, and *New* creates an empty one and opens it. The setup installs a sample database, BCBCM.MDB, in Documents\NutritionModels\BCBCM Files. *Import from Excel* reads animals from an Excel workbook into a new database (Simula.MDB, in the same folder) (Figure 2).

The *Database* submenu contains maintenance commands: *Map* (shows the structure), *Compact*, *Repair*, and *Organize* (removes growth periods and output values for deleted animals). *Copy*, *Rename*, and *Delete* act on the selected file and do not change the database in use.

3.3 *Data > Animals*

Each record describes an animal (or a type of animal): *Animal description*, *Breed code*, *Theta coefficient*, *Initial EBW* and *Mature EBW* (the initial and the mature empty body weight), and *Initial fat %* (the initial percentage of fat). The *Notes* field is for free notes (Figure 3).

The lower part defines what the program reports and when the simulation ends. The *Output variable* and the *End condition* can be *Simulation time*, *Empty body weight*, *Amount of fat in EBW*, or *Percentage of fat in EBW*. In the example in Figure 3, results are requested at given empty body weights, and the simulation ends when the animal reaches 608 kg.

Use *Add* to create a record, *Save* to save the changes, and *Delete* to delete the record. The arrows move through the records.

3.4 *Data > Growth*

Select the animal in the list. Growth is described in periods, numbered in the order they occur (*Period order*). A period can be entered in two ways: by the empty body weight at its end (*EBW at the end*) and *Number of days*, with a constant gain; or by the linear and quadratic coefficients of a growth curve (*Linear coef.*, *Quadratic coef.*), with the number of days (Figure 4).

The lower frame shows the output variable values chosen for the animal. In the example, the animal "*Charolais à pasto*" (Charolais on pasture) has three periods and four output points, in empty body weight: 350, 444, 521, and 608 kg.

Tools > Regression (section 3.7) computes the linear and quadratic coefficients from weighings.

3.5 *Data > Parameters*

The *Parameters* window has two tabs. *Simulation* holds the parameters for numerical integration (largest and smallest step, error tolerance) and the three general model parameters: *KMAX* (0.916), *KMIN* (0.12), and *KLAG* (0.03). *Growth* holds the proportion of protein in the fat-free gain (0.243), the gross energy of protein (5.72 Mcal/kg) and of fat (9.5 Mcal/kg), the factor that converts shrunk body weight into empty body weight (0.891; NRC, 1984), the adjustment factor of NEm (0.89), the number format, and the maximum numbers of growth periods and of variables. The *KMAX* of 0.916 is the estimate of Williams et al. (1995a); *KMIN* differs from the tentative value of Keele et al. (1992), 0.2 (Figure 5).

The values in parentheses are the program defaults. They are stored in the config.dat file in Documents\NutritionModels\BCBCM Files. In most cases, you do not need to change them.

3.6 *Data > Simulations*

The upper list shows the animals in the database. To simulate: (1) click the animal in the upper list; (2) click *Include*, and it moves to the *List of simulations*; (3) repeat for the other animals you want to simulate together; (4) click *Simulate*. *Remove* takes the selected animal off the list (Figure 6).

The results appear in the frame on the right, one line for each output point: the breed code (*Breed*), the time in days (*Time*), the empty body weight in kg (*EBW*), the fat as a percentage of EBW (*Fat*), and NEm and NEg (Mcal/day). The values in parentheses are those accumulated in the period.

Options: *Include the parameter values* writes the parameters used before each result; *Save to file* saves the results in files named Result00.TXT, Result01.TXT, and so on, in the database folder; *Open Notepad* opens the results in Notepad when the simulations end. *Save* saves the frame text and *Clear* clears it. The options checked in the window are remembered from one session to the next.

Sensitivity analysis. The fields at the bottom (*Mature weight*, *Theta*, *Lambda*, *Kmax*, *Kmin*) let you replace a parameter for this simulation only, or vary it over a range. Type one value to use it as a constant, or "start:end;step" to simulate from start to end with the given step. For example, 6:8;0.5 in the *Theta* field simulates *theta* values of 6, 6.5, 7, 7.5, and 8. The program accepts both a comma and a point as the decimal separator.

Graphs. After simulating, choose the kind of graph (fat over days, empty body weight over days, or fat over empty body weight) and click *Draw*. All the simulations of the list are drawn together. With *Keep the existing data in the graph* checked, as it is at the start, each new simulation adds its curves to the earlier ones, so you can compare animals or parameters simulated at different times in one graph; unchecked, each simulation replaces the earlier ones. The *Clear* button of the results clears the stored curves. When you fill a sensitivity analysis field, each curve's legend shows the value used. *Show* brings the graph to the front, *Clear* clears it, and *Save graph* saves the picture (a .wmf file) on the Desktop (Figure 7).

Free windows. With the *Free windows* option checked, graphs open in windows outside the main window, each with its own taskbar button, and can be placed side by side or on another monitor.

R figures. With the option *Use R (high-quality figures)* checked, the graph that is drawn is also drawn by R, as a figure ready for publication: TIFF and PNG files of 1600 x 1600 pixels at 200 dpi, saved in Documents\NutritionModels\BCBCM Files\R Plots with the data of the curves (a CSV file). R must be

installed on the computer (BCBCM does not install it); the figures are drawn with the ggplot2 package, or with R alone if the package is not installed. The file RPlots.def, in BCBCM Files, sets the look of the figures (size, resolution, formats, theme, font, colors, lines, symbols, axes, legend, titles, and the three graphs side by side in one figure), and every setting is explained in the file itself. The start-up report says whether R was found.

3.7 *Tools > Regression*

Type the *X* and *Y* pairs (for example, days and weight) and click *Calculate*. The program fits the linear, quadratic, and cubic regressions and shows the coefficients and r^2. The linear and quadratic coefficients can be used to describe a growth period (section 3.4). *Save* and *Read* save and read the pairs in a file (Figure 8).

3.8 *Help*

The *Help* menu has five items. *Manual and Quick Guide* opens this document in the program's language. *Check for Updates* checks the website for a newer version and, if one is available, shows what is new and downloads the setup file to the BCBCM Files Update folder in a progress window. *Register* shows the registration of the program and, for an evaluation copy or when the version asks for a new code, opens the registration window. *Website* opens the page of the program. *About* opens a window that shows the version, registration, and notice; the buttons in that window (*Register*, *Update*, *Web*, *Sysinfo*, *Help*, and *Return*) perform the same functions, and *Sysinfo* opens System Information in Windows (Figure 9).

3.9 When something goes wrong

When an operation fails, a message gives the error, its code, and where it occurred, and BCBCM stays open; while *Tools > Logs > Save Error Log* is on, the error is also written to BCBCM errors.log. *Tools > Logs > Open Last Start-up Report* opens the report of the start-up checks. A download from *Help > Check for Updates* that is stopped or fails leaves no incomplete file; when it completes, the Update folder opens: close BCBCM, open the zip file, and run the setup program inside it.

3.10 Where the files are

Folder	What it holds
Documents\NutritionModels\BCBCM Files	the sample database (BCBCM.MDB), the database of the breed examples (Breed examples.MDB, section 5), the parameters file (config.dat), and the settings of the figures of R (RPlots.def)
Documents\NutritionModels\BCBCM Files\Logs	the start-up reports and the error log (BCBCM errors.log); Tools > Logs turns either off
Documents\NutritionModels\BCBCM Files\Docs	the spreadsheet Williams simulation.xlsx, with the results of the example in section 4
Documents\NutritionModels\BCBCM Files\R Plots	the figures drawn by R and the data of their curves
Documents\NutritionModels\BCBCM Files\Update	the setup file of a newer version, downloaded by the program
the folder of the database in use	the result files (Result00.TXT, ...)

4. An example: Hereford and Charolais, on pasture and in the feedlot

The sample database holds four cases, with the data of Charles B. Williams's example: Hereford steers (mature empty body weight of 604 kg, *theta* 6.3) and Charolais steers (757 kg, *theta* 7.8), each in two production systems. In the feedlot system ("*em terminação*"), the animal enters the final growth phase directly at the end of the first period (186 days); in the pasture system ("*à pasto*"), it first undergoes a 365-day period of reduced gain. Table 1 summarizes the data entered.

Table 1. Data entered for the four animals of the example.

Animal	Mature EBW (kg)	Theta	Initial EBW (kg)	Initial fat (%)	Growth periods
Hereford em terminação (feedlot)	604	6.3	34	3	to 180 kg in 186 days; then a quadratic curve, 270 days
Hereford à pasto (pasture)	604	6.3	34	3	to 180 kg in 186 days; to 322 kg in 365 days; then a quadratic curve, 136 days
Charolais em terminação (feedlot)	757	7.8	38.2	3	to 193 kg in 186 days; then a quadratic curve, 270 days
Charolais à pasto (pasture)	757	7.8	38.2	3	to 193 kg in 186 days; to 350 kg in 365 days; then a quadratic curve, 136 days

Table 2 presents the simulation results (those in Figure 6) for the four requested weights for each animal.

Table 2. Results of the simulation of the four animals with BCBCM.

Breed	System	Days	EBW (kg)	Fat (%)	NEm (Mcal/d)	NEg (Mcal/d)
Charolais	pasture	549	349.1	14.9	4.17	1.53
Charolais	pasture	596	444.7	20.4	6.61	9.49
Charolais	pasture	631	521.5	24.4	7.68	11.50
Charolais	pasture	669	607.9	28.3	8.64	12.74
Charolais	feedlot	185	192.2	14.3	2.59	2.32
Charolais	feedlot	281	277.5	16.6	4.44	2.80
Charolais	feedlot	362	373.0	20.3	5.69	4.60
Charolais	feedlot	457	512.5	27.8	7.17	7.75
Hereford	pasture	549	321.2	16.7	3.93	1.50
Hereford	pasture	597	428.2	24.4	6.35	11.66
Hereford	pasture	638	502.0	28.7	7.49	10.36
Hereford	pasture	686	563.3	31.8	8.30	7.75
Hereford	feedlot	185	179.2	15.4	2.44	2.26
Hereford	feedlot	258	243.2	18.2	4.13	3.08
Hereford	feedlot	372	348.5	23.4	5.31	3.94
Hereford	feedlot	447	421.3	27.5	6.48	5.06

Figure 10, at the end of this section, presents these results with fat against empty body weight (Figure 7 presents them over time, as the program draws them). Two effects deserve attention.

At the same weight, the animal of smaller mature size is fatter. The Hereford, with a mature empty body weight of 604 kg, always lies above the Charolais (757 kg) in the same system because, at the same weight, it is more mature.

At the same weight, the animal that grew faster is fatter. The feedlot animals, which reached that weight sooner, carry more fat than those that first went through a year of reduced gain on pasture. Interpolating the results to 400 kg of empty body weight, fat is 17.8% for the Charolais on pasture and 22.3% for the Charolais in the feedlot, and 22.0% for the Hereford on pasture and 26.2% for the Hereford in the feedlot.

This is the model's answer to the question that gave rise to the program: weight alone does not determine body composition; the animal's mature size and growth rate also determine it.

The same results are in the spreadsheet Williams simulation.xlsx, installed in Documents\NutritionModels\BCBCM Files\Docs, which plots them as in Figure 10 and interpolates to 400 kg. The weights, in the spreadsheet as in the program, are empty body weights.

5. Breed examples: the 17 biological types of Williams et al. (1995a)

A second database, Breed examples.MDB, installed beside the sample database, holds one steer of each of the 17 biological types for which Williams et al. (1995a) estimated the parameters of the model, from the data of the Germ Plasm Evaluation Program of the U.S. Meat Animal Research Center: purebred Hereford and Angus, their cross, and the crosses of 14 sire breeds with Hereford and Angus dams (for example, Jersey cross = ½ (Jersey × Hereford + Jersey × Angus)). This is meant as a starting point: to simulate an animal of one of these types, take its *theta* and mature weight from the database, and enter the animal's growth.

Table 3 lists the two parameters of each type. The mature fat-free matter (**FFM**) of steers and *theta* are the values reported in Table 5 of that paper; the program asks for mature empty body weight, which is mature fat-free matter divided by 0.749, because the model assumes the mature animal is 25.1% fat. The same table compares the fat simulated by BCBCM at empty body weight at slaughter with the observed fat, both taken from Table 5.

Table 3. Parameters of the 17 biological types (Table 5 in Williams et al. (1995a)) as entered in Breed examples.MDB, and the empty body fat at slaughter, observed and simulated by BCBCM.

Biological type	Mature FFM, steers (kg)	Mature EBW (kg)	Theta	EBW at slaughter (kg)	Observed fat (%)	Simulated fat (%)	Difference
Jersey cross (JX)	402	537	5.59	396	31.1	30.3	−0.8
Hereford (HH)	437	583	6.30	404	28.4	27.0	−1.4
Angus (AA)	416	555	5.97	410	30.7	29.4	−1.3
Hereford x Angus (HAX)	430	574	6.00	417	30.5	29.1	−1.4

Biological type	Mature FFM, steers (kg)	Mature EBW (kg)	Theta	EBW at slaughter (kg)	Observed fat (%)	Simulated fat (%)	Difference
Red Poll cross (RX)	439	586	5.63	401	29.0	27.1	−1.9
South Devon cross (SDX)	462	617	6.47	434	29.5	28.7	−0.8
Tarentaise cross (TX)	468	625	6.38	434	27.6	28.1	+0.5
Pinzgauer cross (PX)	474	633	6.14	428	27.3	27.8	+0.5
Sahiwal cross (SaX)	416	555	6.72	417	28.1	28.4	+0.3
Brahman cross (BrX)	523	698	5.58	449	27.8	28.5	+0.7
Brown Swiss cross (BX)	482	644	7.35	438	26.4	24.8	−1.6
Gelbvieh cross (GX)	524	700	6.64	444	26.2	24.6	−1.6
Simmental cross (SX)	516	689	7.24	444	26.1	25.2	−0.9
Maine Anjou cross (MX)	605	808	6.19	454	25.5	23.8	−1.7
Limousin cross (LX)	501	669	7.41	432	25.7	24.8	−0.9
Charolais cross (CX)	545	728	7.51	457	25.7	24.9	−0.8
Chianina cross (CiX)	563	752	7.86	445	22.8	21.5	−1.3

Each animal's growth follows the steer data in Table 3 of the same paper, in three periods: constant gain from birth to weaning, constant gain during the conditioning period, and a quadratic curve during the finishing period (Table 4). The paper reports body weights, and the program uses empty body weight, so we converted the weights accordingly. Empty body weight at birth is body weight × 0.956 and at weaning body weight × 0.86, as in the paper. We also multiplied the weight at the end of the conditioning period by 0.86, an assumption in this document: the paper calculated that weight from the diet but did not report it. The linear and quadratic coefficients of the regression of body weight on days on feed were multiplied by one factor, such that the animal reaches the empty body weight at slaughter of Table 5 on the last day on feed. The initial fat is 2.6% of the empty body weight (Williams et al., 1995b). For Hereford, Angus, and Hereford × Angus, which were evaluated in more than one program cycle, we used the cycle means, as the paper did for *theta*.

Table 4. Growth periods entered for the 17 biological types, in empty body weight, derived from Table 3 of Williams et al. (1995a).

Biological type	Initial EBW (kg)	Weaning: EBW (kg), age (d)	Start of finishing: EBW (kg), days	Days on feed	Linear coefficient	Quadratic coefficient
Jersey cross (JX)	29.6	172.0, 215	190.1, 25	217	1.08491	−0.0006270
Hereford (HH)	35.9	158.7, 200	181.0, 34	232	1.21068	−0.0010753
Angus (AA)	32.5	167.7, 200	192.6, 34	232	1.18028	−0.0010483
Hereford x Angus (HAX)	35.1	171.7, 199	199.5, 35	225	1.19340	−0.0010077
Red Poll cross (RX)	36.3	154.8, 185	187.5, 42	246	1.02470	−0.0006374
South Devon cross (SDX)	35.4	182.3, 215	195.2, 25	217	1.33823	−0.0010957
Tarentaise cross (TX)	37.3	182.3, 196	214.1, 38	211	1.23969	−0.0009361
Pinzgauer cross (PX)	39.2	178.0, 196	207.3, 38	211	1.27639	−0.0010920
Sahiwal cross (SaX)	38.2	180.6, 196	207.3, 38	211	1.10327	−0.0005186
Brahman cross (BrX)	41.1	190.1, 196	220.2, 38	211	1.26564	−0.0008591

Biological type	Initial EBW (kg)	Weaning: EBW (kg), age (d)	Start of finishing: EBW (kg), days	Days on feed	Linear coefficient	Quadratic coefficient
Brown Swiss cross (BX)	39.2	164.3, 185	199.5, 42	246	1.10271	−0.0005414
Gelbvieh cross (GX)	40.2	167.7, 185	204.7, 42	246	1.09421	−0.0004937
Simmental cross (SX)	38.2	190.9, 215	205.5, 25	217	1.23886	−0.0006442
Maine Anjou cross (MX)	42.1	165.1, 185	208.1, 42	246	1.18722	−0.0007627
Limousin cross (LX)	36.3	184.9, 215	200.4, 25	217	1.27487	−0.0009566
Charolais cross (CX)	38.2	193.5, 215	211.6, 25	217	1.39003	−0.0011943
Chianina cross (CiX)	41.1	166.0, 185	206.4, 42	246	1.09359	−0.0005027

Note on the Pinzgauer cross. Table 3 of the paper prints the quadratic coefficient for this type as 0.00121 (positive), whereas that for every other type is negative. We took this as a misprint and entered it as negative (−0.00121, before conversion to empty body weight).

The simulated fat differs from the observed fat by −0.9 percentage points on average (from −1.9 to +0.7), and the root mean square difference is 1.2 percentage points. Agreement is expected because the paper estimated *theta* so that the model would reproduce these observations. The differences that remain come from the conversions described above, which are not those of the paper day by day (there the ratio of empty body weight to body weight rises along a curve during the finishing period); from the means of the cycles; and from the other parameters of the model, which the paper took from Keele et al. (1992) and which in BCBCM are those of the code Williams sent in 1995 (section 1.1). These animals show how to enter the published parameters in the program; they are not a new evaluation of the model.

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Figures

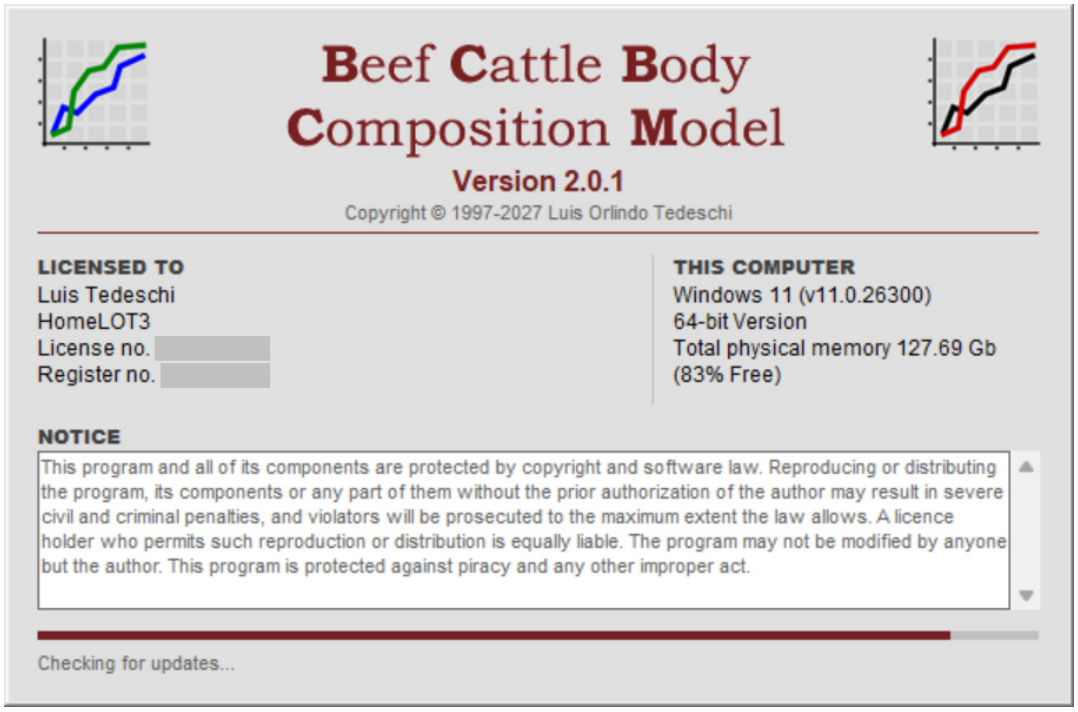

Figure 1. The splash screen of BCBCM. The license and register numbers are grayed out for privacy.

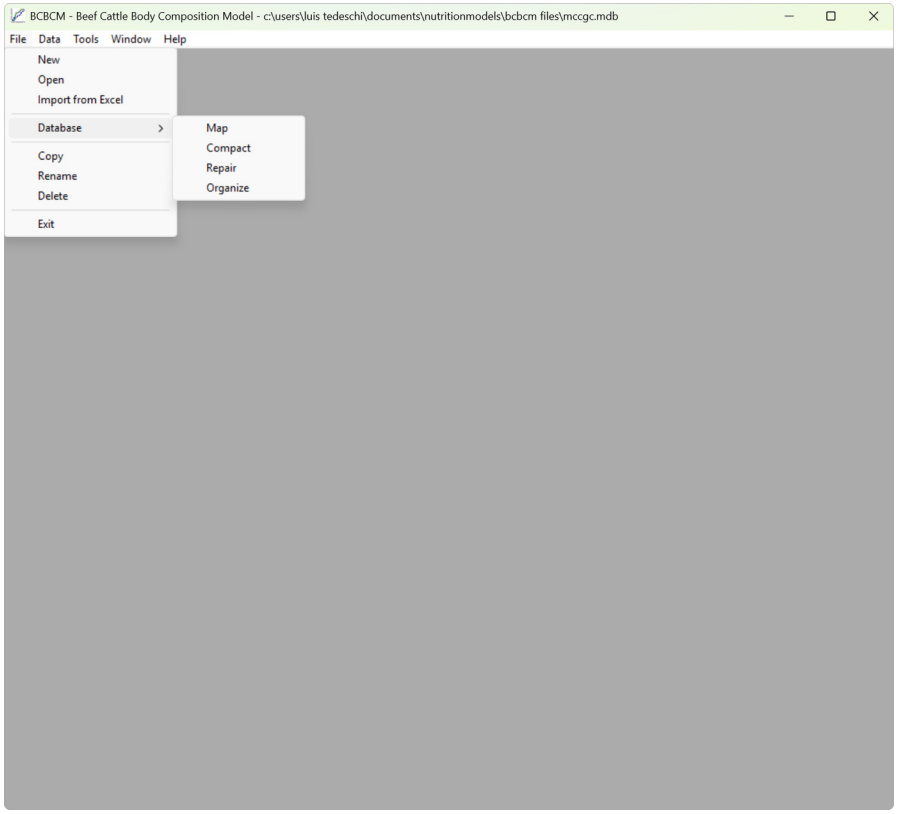

Figure 2. The main window of BCBCM, with the *File* menu and the *Database* submenu.

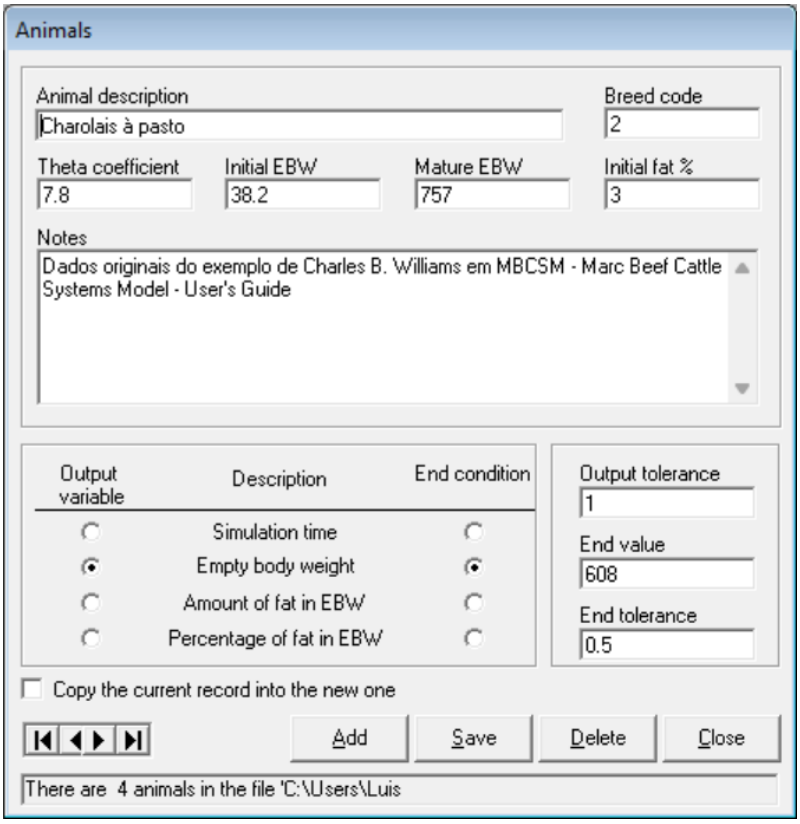

Figure 3. The animals.

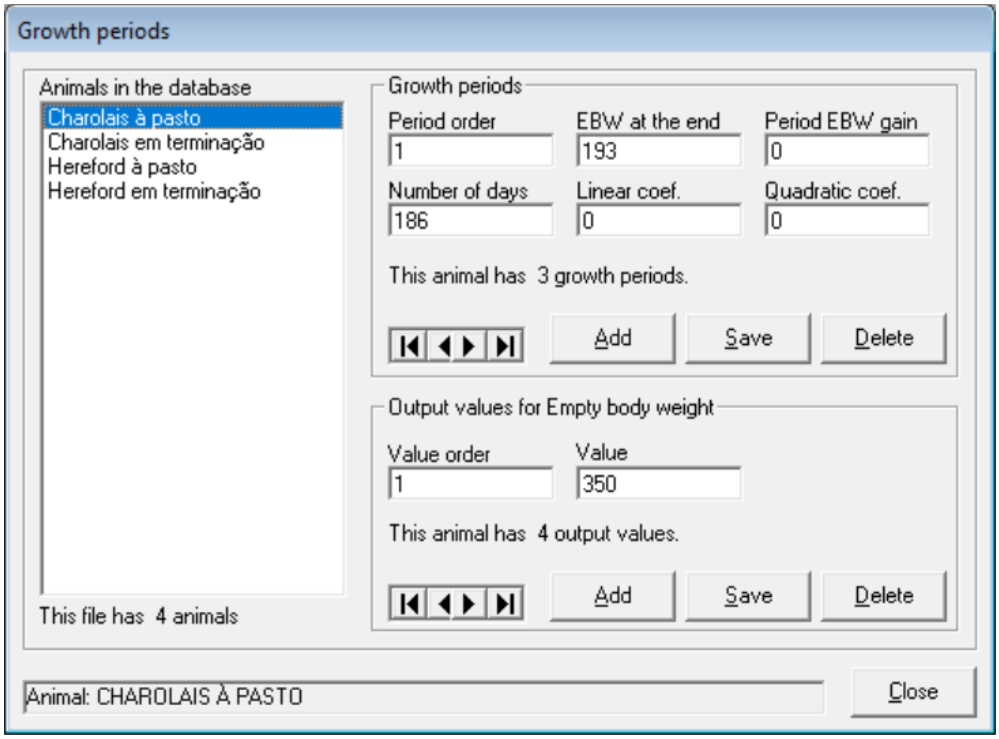

Figure 4. Growth periods and output points of each animal.

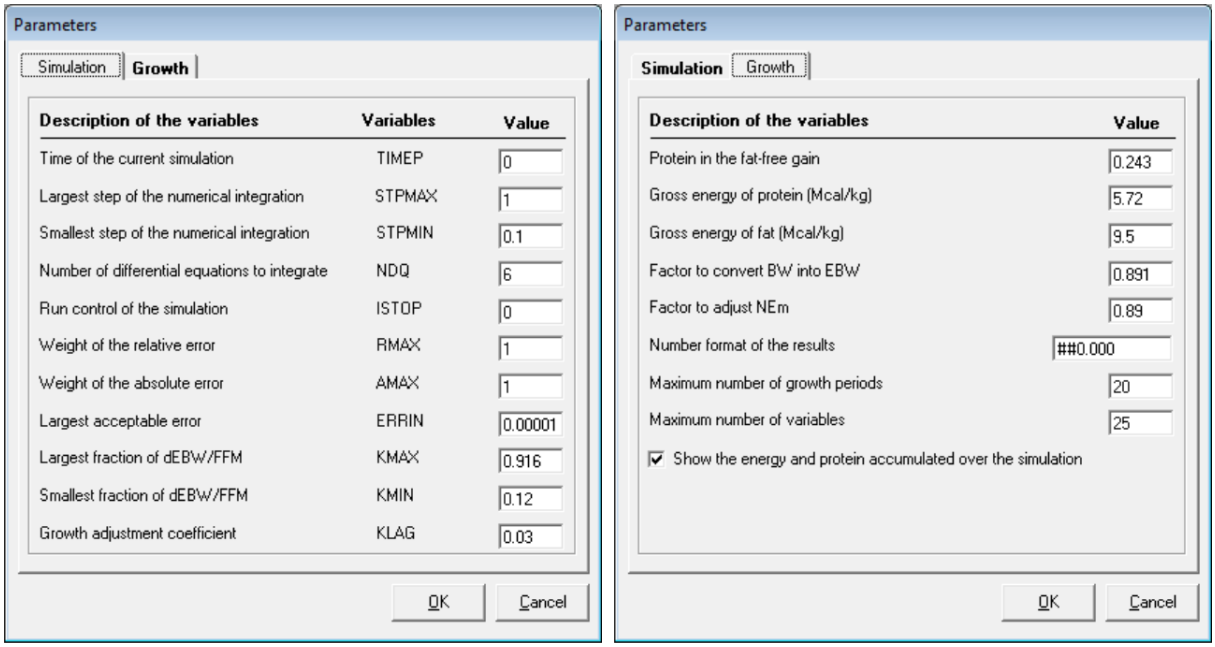

Figure 5. Parameters of the model: (a) the *Simulation* tab; (b) the *Growth* tab.

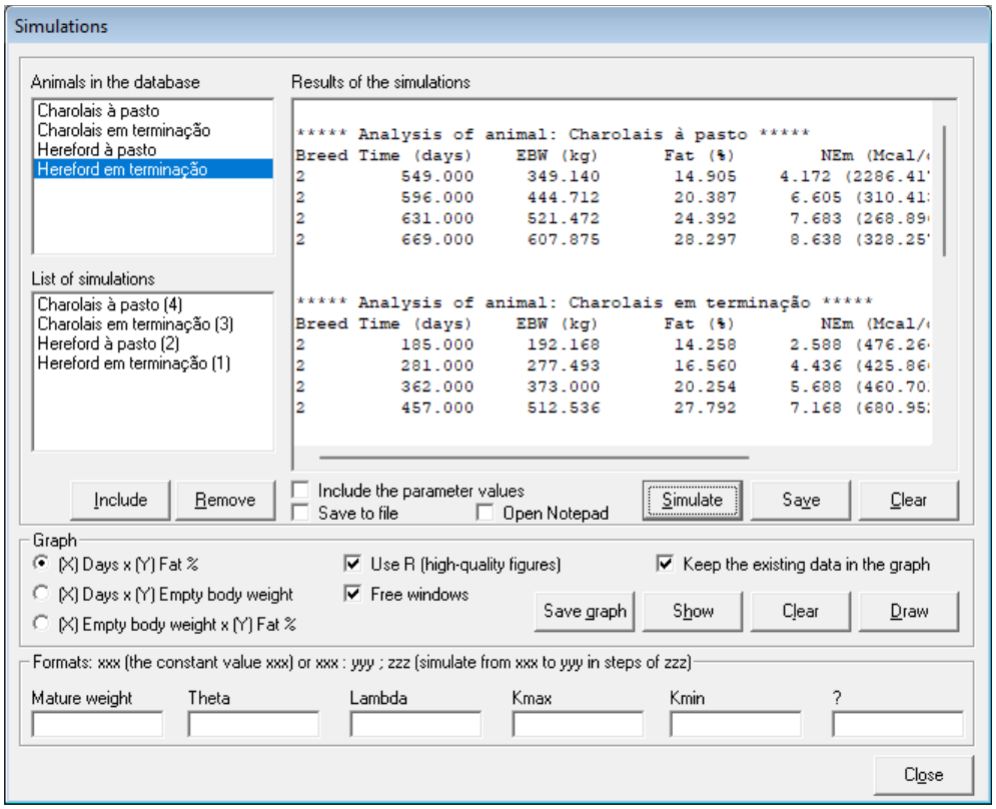

Figure 6. Simulation of the four animals of the sample database.

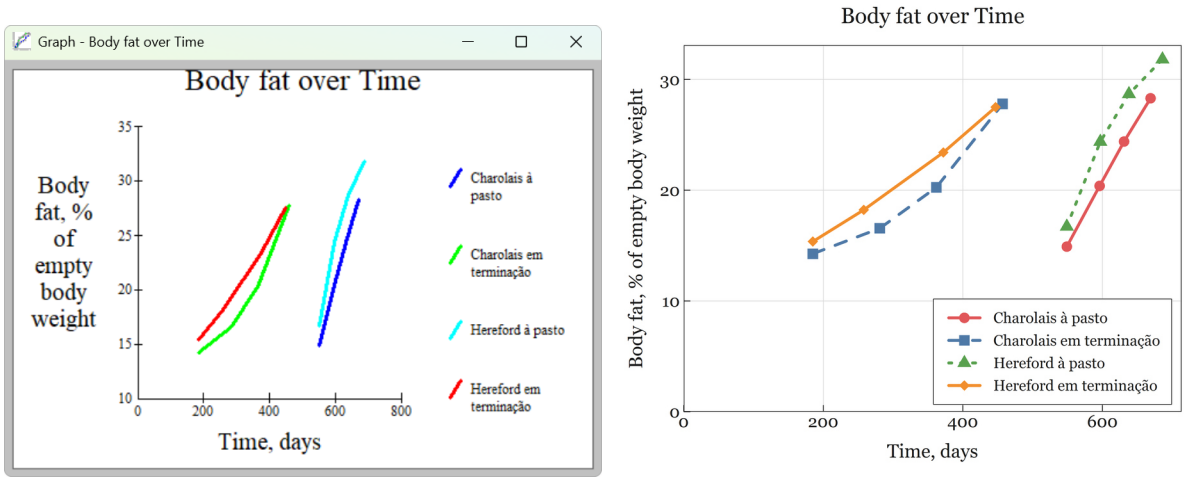

Figure 7. Body fat over time for the four simulations: (a) the graph window of the program; (b) the figure drawn by R.

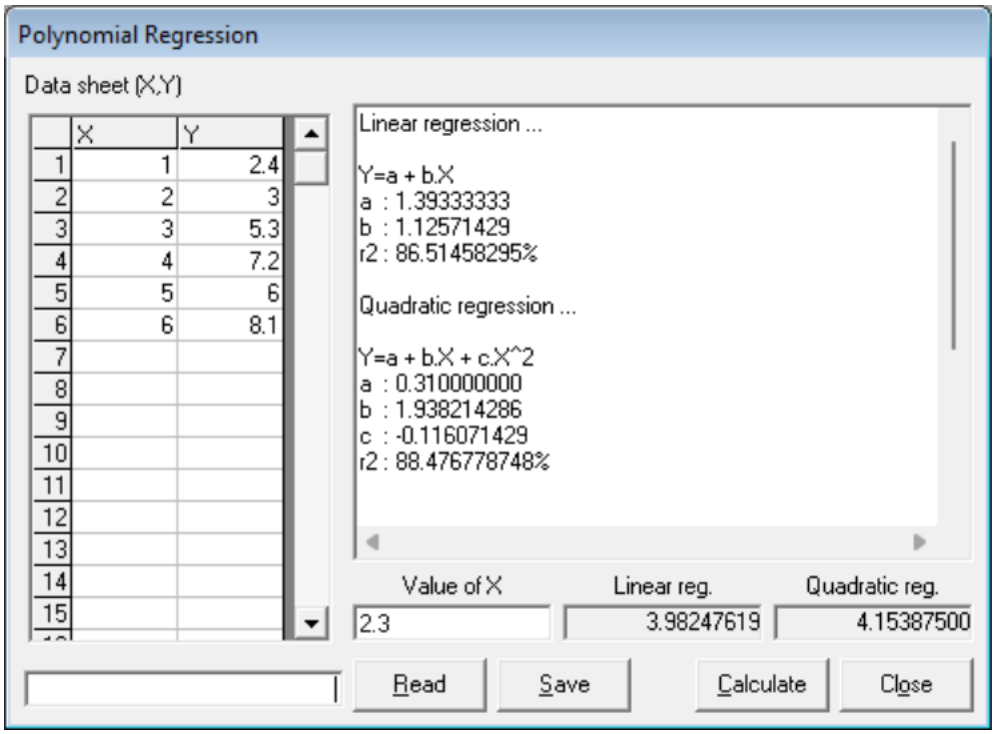

Figure 8. Polynomial regression.

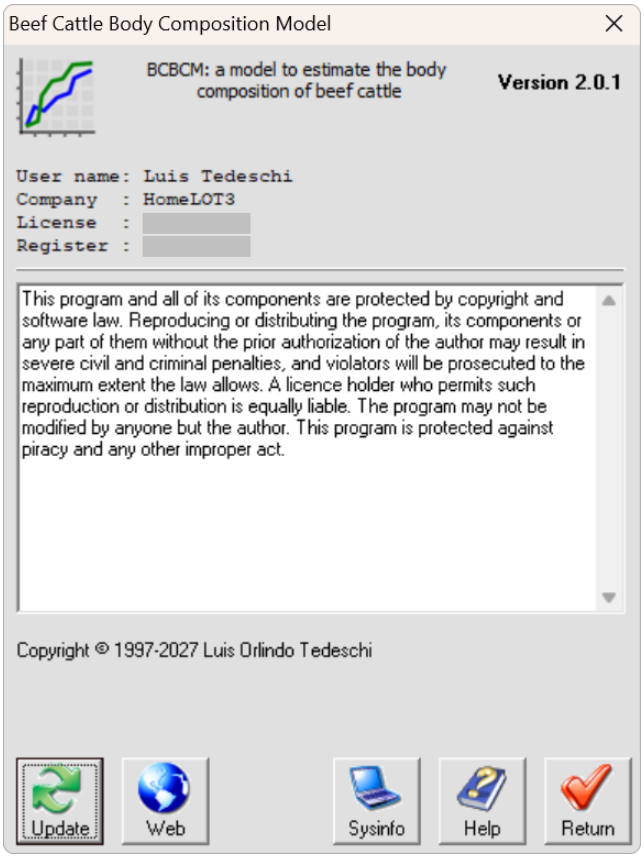

Figure 9. The About window. The license and register numbers are grayed out for privacy.

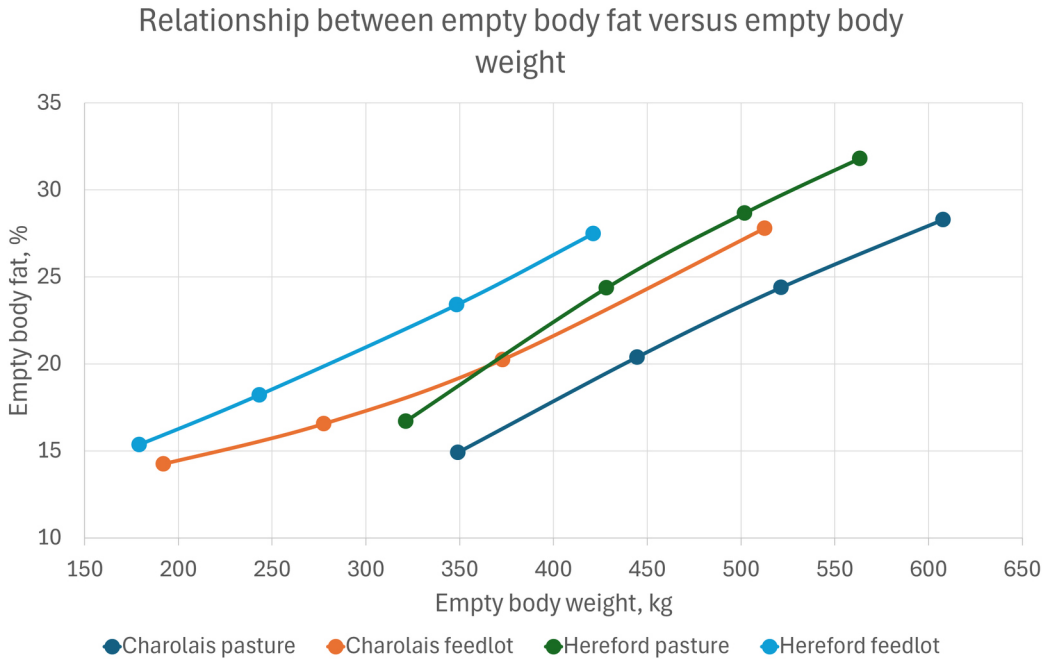

Figure 10. Body fat against empty body weight of the four animals, drawn by the spreadsheet Williams simulation.xlsx.