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The substitution of cacao fruit husk for cut grass in the feeding of beef cattle – simulation with an econometric model

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Abstract

Several projects have been completed for the productive use of the unused cacao husk, residue of the cacao production system. Among many considerations of use there is the utilization of the husk as a bulking component for monogastric and ruminant feeding. CEPEC - the Cacao Research Center in Bahia, Brazil has done research on this and published the results. Besides zootechnical material CEPEC has released economic studies and evaluation on the use of fresh chopped cacao husk for cattle feeding. Utilizing previously obtained econometric models, this paper reviews the substitution of cacao husk for grass in order to quantify the productive relationship of the two inputs.

Key words: *Theobroma cacao,* fruit, husk, grass, beef cattle, substitution, econometric model, simulation

Substituição de capins por casca de fruto do cacaueiro na alimentação de gado de corte – simulação com um modelo econométrico

Resumo

Inúmeros trabalhos foram elaborados sobre o emprego produtivo da casca do fruto, resíduo decorrente do sistema de produção de cacau. Entre as muitas sugestões de uso deste resto de cultura, destaca-se a que indica sua utilização como ingrediente (volumoso) da alimentação de monogástricos e ruminantes. O Centro de Pesquisas do Cacau (CEPEC) desenvolveu investigações neste sentido, já tendo inclusive liberado informações sobre o tema. Além de considerações zootécnicas, o CEPEC divulgou estudos e avaliações econômicas sobre a alimentação de bovinos com casca de cacau *in natura*, picada. O presente estudo particulariza o problema da substituição de capins por casca de cacau, pondo a funcionar modelos econométricos já anteriormente obtidos, visando a quantificação de relação entre os dois insumos.

Palavras-chave: *Theobroma cacao,* fruto, casca, capim, gado de corte, substituição, modelo econométrico, simulação

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Introduction

Among underdeveloped nations, where the problems of the lack of and the injurious distribution of wealth have been identified, there is a dramatic waste of resources. Some of those countries produce cacao, one of the most important commodities traded in the international market. In this segment of agricultural production, only the least part of the fruit is used as a commodity – the beans. The pod of the fruit is usually unused. However, several programs have been conducted by agricultural researchers on the economic employment of that and other cacao waste as well as by-products. Among them one can cite e.g., De Alba et al (1954), Fresnillo (1962), Bateman and Larragan (1966), Llamosas (1976) and Opeke (1984). Further, CEPEC the Cacao Research Center of CEPLAC has demonstraded that it is feasible to use cacao fruit husk to feed both beef and dairy cattle, Ferreira et al (1985) have studied econometrically the production of beef cattle as a function of the following nutriments: grassland grass, cut grass and fresh chopped cacao husk as bulky ingredients.

Based on the latter paper it is possible to quantify the relationship between nutrient inputs in the beef cattle breeding process under local conditions. Thus the mixed farms of South Bahia which have both cacao and beef cattle can be informed of how and how much to substitute cacao fruit husk for grass without loss in yield, within certain conditions, with two advantages: to embody previously wasted material into the production process and to avoid or to decrease the use of cut grass.

Indeed this is the main objective of this work: to show a device which can quantify the relationship among the bulk nutriments (assuming as constant the concentrated feed, as in the experiment that yielded elements for this study).

Material and Methods

The trial was conducted at CEPEC, Ilhéus, Bahia, Brazil, from November, 1980 to February, 1981. Thirty-five half-blooded two-year old steers 250 kg live weight (average) were used in seven treatments, each one being characterized by different bulk (grassland grass, cut grass and cacao fruit husk) and concentrate (corn and urea) feed combinations and by management (Ferreira at al., 1985).

The economic evaluation was performed by fitting Cobb-Douglas type production function to only two treatments, those which do not have zero values for any independent variable according to the requirement of that kind of function.

Henderson and Quant (1971) say that "the entrepreneur's production function gives mathematical expression to the relationship between the quantities of inputs he employs and the quantities of outputs he produces". "Consider a simple production process in which an entrepreneur utilizes two variable inputs (X_1 and X_2) and one or more fixed inputs in order to produce a single output (Q). His production function states the quantity of his output (q) as a function of the quantities of his variable inputs (x_1 and x_2):

$$q = f\ (x_1, x_2) \qquad (1)$$

where (1) is assumed to be a single-value continuous function with continuous first and second-order partial derivatives. "........" an isoquant is the locus of all combinations of x_1 and x_2 which yield a specified output level. For a given output level, (1) becomes

$$q^0 = f\ (x_1, x_2) \qquad (2)$$

where q^0 is a parameter. The locus of all combinations of x_1 and x_2 which satisfy (2) forms an isoquant ".......''The slope of the tangent (geometric) to a point on an isoquant is the rate at which X_1 must be substituted for X_2 (or X_2 for X_1) in order to maintain the corresponding output level. The negative of the slope is defined as the rate of technical substitution (RTS) (which in this work will be called "marginal rate of technical substitution):

$$MRTS = - \frac{dx_2}{dx_1} \qquad (3)".$$

Ferguson (1972) shows similar definition of what he calls marginal rate of technical substitution.

Marginal rate of technical substitution of the input X_j for X_i ($MaRTS_{X_jX_i}$) is the quantity of X_1 (substituted input) which will be exactly compensated by an additional quantity of X_j (substitute input) in order to prevent a production level variation.

That is an intuitional definition, besides the more operational previous one. Nevertheless, like the other, it can give place to an analytical expression, obtainable from continuous production function:

$$MaRTS_{X_jX_i} = \frac{-\partial_{xi}}{\partial_{xj}} \qquad (4)$$

It's easily demonstrable that

$$MaRTS_{X_jX_i} =$$

$$= (MaPP_{X_j})\ .\ (MaPP_{X_i})^{-1} \qquad (5)$$

where $MaPP_X$ means "marginal physical production of X factor or input".

Starting from (5), one can demonstrate that for the Cobb-Douglas production function the marginal rate of technical substitution is a linear function of the inputs ratio (X_i/X_j), with the slope b_j/b_i and zero linear coefficient:

$$MaRTS_{X_jX_i} = (b_jX_i)\ (b_iX_j)^{-1}$$

or

$$MaRTS_{X_jX_i} = b_j/b_i\ .\ (X_i/X_j) \quad (6)$$

in the case of a two input production function.

So, for this special production function the marginal rate of technical substitution is a linear function of the ratio "substituted input/substitute input" or, in other words, that rate of substitution changes with the production process (quantity of used inputs) and not with the level of production, within a given production process. That is a Cobb-

Douglas model feature: if a production process (or input ratio) is given, the $MaRTS_{X_jX_i}$ remains the same for any production level. The $MaRTS_{X_jX_i}$ should be calculated for production process or input ratio, without reference to produced quantity.

In order to understand the form of the relationship among the three variables, (6) one can take the following form:

$$MaRTS_{X_jX_i} = a.X_iX_j^{-1} \qquad (7)$$

whose form may be perceived by orthogonal cuttings in the surface of production or, in other words, fixing the quantity of one input in a certain level and studying the ralationship between the MaRTS and the other input.

In this case, fixing the substitute input (X_j), one can study the association between the MaRTS and the substituted input (X_i):

$$MaRTS_{X_jX_i} = k_iX_i \qquad (8)$$

which is linear, with a positive association between the two variables, i. e., the MaRTS increases with the level of use of X_i.

In respect to the association between the MaRTS and the substitute input (X_j), by fixing the substituted input (X_i), one obtains:

$$MaRTS_{X_jX_i} = k_2X_j^{-1} \qquad (9)$$

meaning that the relation is a negative association: the MaRTS decreases when the substitute input (X_j) increases. Besides, (9) takes a especial shape, with MaRTS taking big values to the small values of X_j, MaRTS trending to infinity when X_j trends to zero and MaRTS taking small values to the big values of X_j, MaRTS trending to zero when X_j trends to infinity. In other words, in this case, the function becomes asymptotic to both the orthogonal axes. It is a "rectangular hyperbola function".

In the present work, the marginal rate of technical substitution may be empirically utilized to state how much of one input must be used in place of another in order to not change the level of meat production. Of course, that is an important item, as the cacao fruit pod is a wasted resource.

The selected methodology presumes a production function with substitutable production factors, as defined by Simonsen (1979), i. e. with differenciable isoquants in all their points or permiting infinite production processes.

The production function fitted to the experimental data and from which the $MaRTS_{X_jX_i}$ was obtained was:

$$Y_i = 32.37\,X_{1i}^{0.73} \,.\, X_{2i}^{0.12} \,.\, X_{3i}^{0.13} \,.\, u_i \qquad (10)$$

t Student test

(6.66) * *(5.05) * * (4.64) * *

confidence interval

±0.40 ±0.09 ±0.10

$F = 14.95^{**}$

$R^2 = 0.88$

$\bar{R}^2 = 0.82$

where

Y_i = Final weight of the "i-th" animal, in kg

X_{1i} = Daily average grassland grass consumption by the "i-th" animal

X_{2i} = Daily average cut grass consumption by the "i-th" animal, in kg

X_{3i} = Daily average cacao fruit pod consumption by the "i-th" animal, in kg

u_i = Disturbance or error term

** = 1% probability significance level.

Results and Discussion

According to the method previously stated, all the six possible marginal rates of technical substitution functions for this case (see Table 1) were set up.

As one can see, the quantity of substituted input, which may be replaced by the substitute input without change in the production level, does not depend on the quantity produced. It is a function only of the amount of the related inputs.

It is worth noticing that comparing the two functions whose inputs change the roles (substitute/substituted), their angular coefficients are, as expected, the inverse of each other. Thus, for the inputs cacao fruit pods (X_{3i}) and cut grass (X_{2i}) such values are 0.92 and 1.08. As a matter of fact, in all the three symmetric pairs of functions in relation to the principal diagonal, this property is verifiable.

Table 1 - Matrix of marginal rate of technical substitution functions between each couple of input.

Substitute input	Substituted input		
	Grassland grass (X_{1i})	Cut grass (X_{2i})	Cacao fruit pod (X_{3i})
Grassland grass (X_{1i})	—	$MaRTS_{X_{1i}X_{2i}} = 6.09\ X_{2i}X_{1i}^{-1}$	$MaRTS_{X_{1i}X_{3i}} = 5.61\ X_{3i}X_{1i}^{-1}$
Cut grass (X_{2i})	$MaRTS_{X_{2i}X_{1i}} = 0.16\ X_{1i}X_{2i}^{-1}$	—	$MaRTS_{X_{2i}X_{3i}} = 0.92\ X_{3i}X_{2i}^{-1}$
Cacao fruit pod (X_{3i})	$MaRTS_{X_{3i}X_{1i}} = 0.18\ X_{1i}X_{3i}^{-1}$	$MaRTS_{X_{3i}X_{2i}} = 1.08\ X_{2i}X_{3i}^{-1}$	—

A knowledge of this matrix is valuable to a farm policy-maker. It is possible from its MaRTS functions to determine a plane of substitution among each pair of ingredientes in the feeding process of beef cattle of the farm in order to maintain the average level of production per animal.

Each one of the six econometric models in Table I may be used to determine what quantity of the substituted input must be replaced by one unit of the substitute factor. This value, which is, by definition, the MaRTS, depends, according to the form of the MaRTS function, on the level of use of each factor, i. e., on the production process.

In this paper only one of the six models was used in the simulation. The others may be used similarly. The elected model was just that one which links cacao fruit pod, as the substitute input, and cut grass as the substituted one. Certainly, that is the situation with greatest empirical applicability in Bahian Cacao Growing Region.

For the simulation process, six different levels of daily average individual consumption of cacao shell as well as of cut grass were selected. The levels were chosen randomly among the recorded values of the trial.

Of course, each number in that table means how many kg/animal/day of cut grass must be substituted by one additional kg/animal/day of cacao fruit shell, without demage to meat production, in the particular level of input utilized indicated by the row and the column.

The scores of the MaRTS, in this case, corroborate the previous statement about their behaviour.

Figure 1 shows the graphic expression of the MaRTS function used in simulation, i. e. MaRTS $X^{-1}_{3i} X_{2i} = 1.08$ $X_{2i} X_{3i}$. Confirming the expected, the relationship among the three variables is

Table 2 - MaRTS$_{X_{3i}\ X_{2i}}$ interchangeable quantities of input without demage to meat production: substitution of cacao fruit husk for cut gras (kg/animal/day) - MaRTS$_{X_{3i}X_{2i}} = 1.08\ X_{2i}X_{3i}^{-1}$.

Quantity of substitute input: cacao fruit husk (X_{3i}) (kg/animal/day)	Quantity of substituted input: cut grass (X_{2i}) (kg/animal/day)				
	3.1	4.6	6.0	8.5	17.5
3.3	1.01	1.51	1.96	2.78	5.73
4.2	0.80	1.18	1.54	2.18	4.50
5.9	0.57	0.84	1.09	1.56	3.20
9.0	0.37	0.55	0.72	1.02	2.10
18.3	0.18	0.27	0.35	0.50	1.03

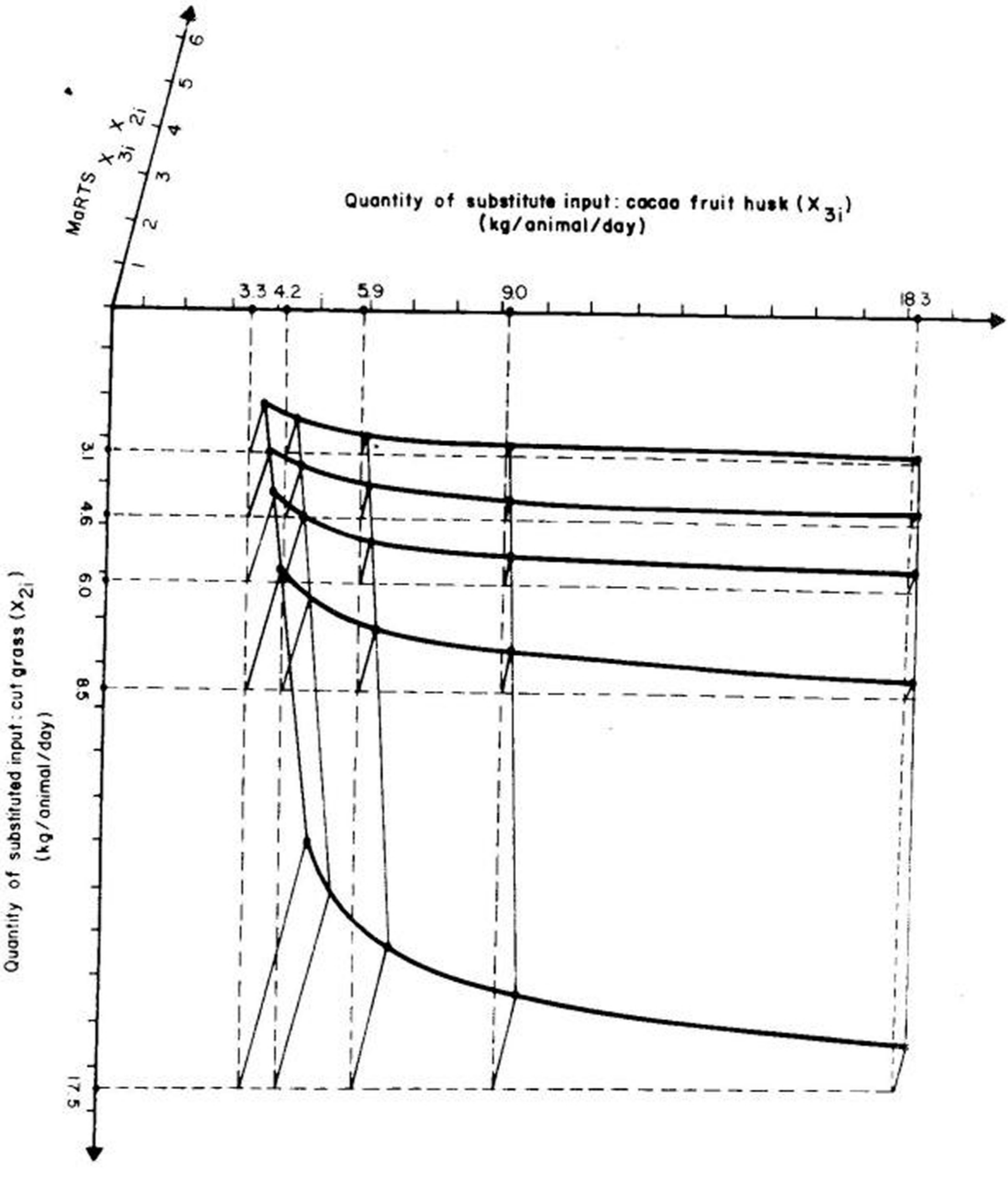

Figure 1 – Relationship between $MaRTS_{X_{3i}X_{2i}}$ and the prevalent level of the two inputs used.

defined by a surface as previously described in "Material and Methods".

Cutting the surface at fixed levels of each one of the inputs, one can see the shapes of relationships between the MaRTS and each input. As seen in Figure 2 they obey the discription given in "Material and Methods".

Those results were obtained by modeling and simulation techniques, which permit readily an examination of what happens in model world. It would be productive to compare them with actual results.

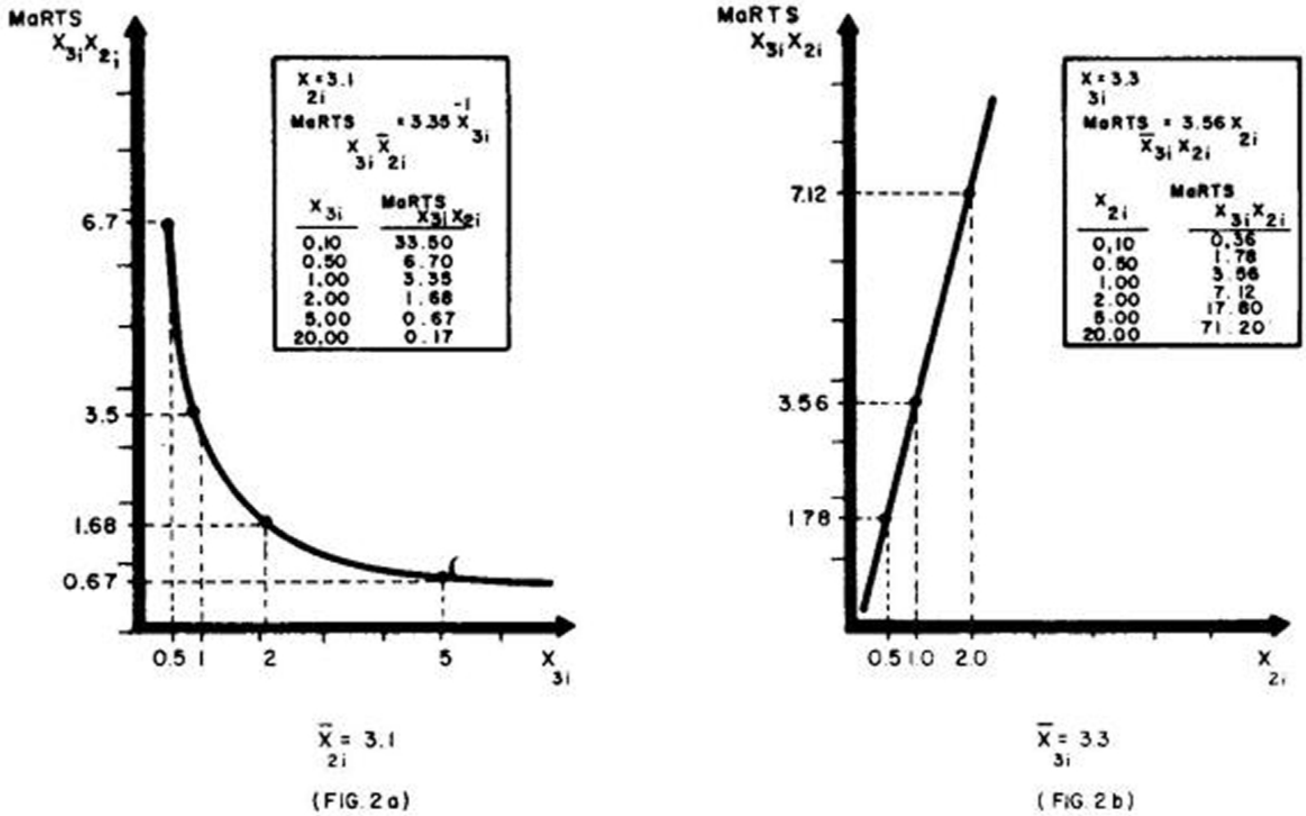

Figure 2 – The shape of relationships between the MaRTS and each one of the inputs.

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