A DECISION SUPPORT SYSTEM TO AID THE CALCULATION OF THE COST OF THE POST-HARVEST PROCESSING OF COFFEE

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ABSTRACT: Various computer programs were developed to calculate the cost of the coffee harvest. However, few address the costs of coffee in its post-harvest stage. This study was aimed to develop a system for calculating the cost of the coffee post-harvest to facilitate decision making regarding the most cost-effective post-harvest processes. Thirty-four farmers in southern Minas Gerais state answered a questionnaire designed to validate this system. The use of a decision support system showed that the simulated costs in the post-harvest stage were not statistically different from the costs informed by the representatives of the selected farms.

Index terms: Coffee processing, computer program, simulation, modeling

Pós-Café: UM SISTEMA DE APOIO À DECISÃO PARA O CÁLCULO DO CUSTO DA PÓS-COLHEITA DO CAFÉ

RESUMO: *Vários programas computacionais foram desenvolvidos para calcular o custo da colheita do café. No entanto, poucos abordam os custos da fase de pós-colheita do café. Objetivou-se, neste trabalho, desenvolver um sistema de cálculo do custo da pós-colheita do café para facilitar a tomada de decisão quanto aos processamentos de melhor custo-benefício. Trinta e quatro fazendas do sul de Minas Gerais responderam a um questionário elaborado para validar esse sistema. Ao empregar o sistema de apoio à decisão, foi constatado que os custos simulados na fase de pós-colheita não diferem estatisticamente dos custos informados pelos responsáveis das fazendas entrevistadas.*

Termos para indexação: *Pós-colheita do café, programa computacional, simulação, modelagem.*

1 INTRODUCTION

In view of the rapid recent expansion of the specialty coffee market with increasingly demanding consumers, it is essential to improve the quality of the beverage in order to meet market demand and increase the income of the grower (MENDONÇA et al., 2007; RESENDE et al., 2011; SAATH et al., 2010). One of the determining factors for this situation is the post-harvest processing (ABRAHÃO et al., 2010). Borém (2008) affirm that most agricultural issues related to Brazilian coffee production had a very favorable evolution. However, there is lack of information on the management of technology knowledge. Such information could help us ensure high quality and low cost for the post-harvest processing of coffee.

For coffee growers, consultants and cooperatives involved in the post-harvest handling and processing of coffee, it is still difficult to decide which post-harvest process is the most suitable because there are many variables involved (climate variations, availability of infrastructure and capital, etc.) (Figure 1). Many aspects should be considered to facilitate the decision making of growers, consultants and cooperatives.

According to Field, Kirchain and Roth (2007) and Valente et al. (2011), determination of costs is relevant for this analysis and essential for decision makers.

Due to the large number of variables that influence the costs of coffee processing in the post-harvest stage, the present study aimed to develop a decision support system to determine the costs of reception, centrifuging, peeling, pulping, mucilage removal, wastewater treatment and coffee drying.

The purpose is to systematize the existing knowledge in the field in order to facilitate a decision regarding the most cost-effective post-harvest processes, as well as to raise awareness among producers of the importance of previously

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neglected factors, and, finally, to clarify some critical points regarding processes already in use.

2 MATERIAL AND METHODS

Definition of coffee processing in the post-harvest stage

The first stage of this study comprised the selection of the several types of coffee produced: natural coffee, floater coffee, coffee cherry and green coffee, green coffee, peeled coffee cherry, coffee cherry without mucilage and pulped coffee cherry. All these types of coffee can be dried in the sun on a patio or in an oven dryer.

Definition of the processing costs to be calculated

At this stage, the costs to be calculated for post-harvest processing were defined.

Table 1 shows the major costs calculated by the system, as well as a summary of their formulas. Costs are calculated per bag of coffee.

Identification of the variables needed to calculate the defined costs

Once the main costs involved in post-harvest processing of coffee are defined, the variables required to calculate these costs are determined.

Based on the formulas of the cost variables (Table 1), the following input variables were defined as necessary parameters: production (bags), harvest time (days), percentage of coffee cherry at the beginning of harvest, percentage of green coffee fruits at the beginning of harvest, percentage of floater coffee at the beginning of harvest, value of tariff (R$/kWh), man cost per day (R$), Price of the standard coffee bag (R$), Price of the bags of each type of coffee (R$), type of patio, fermentation

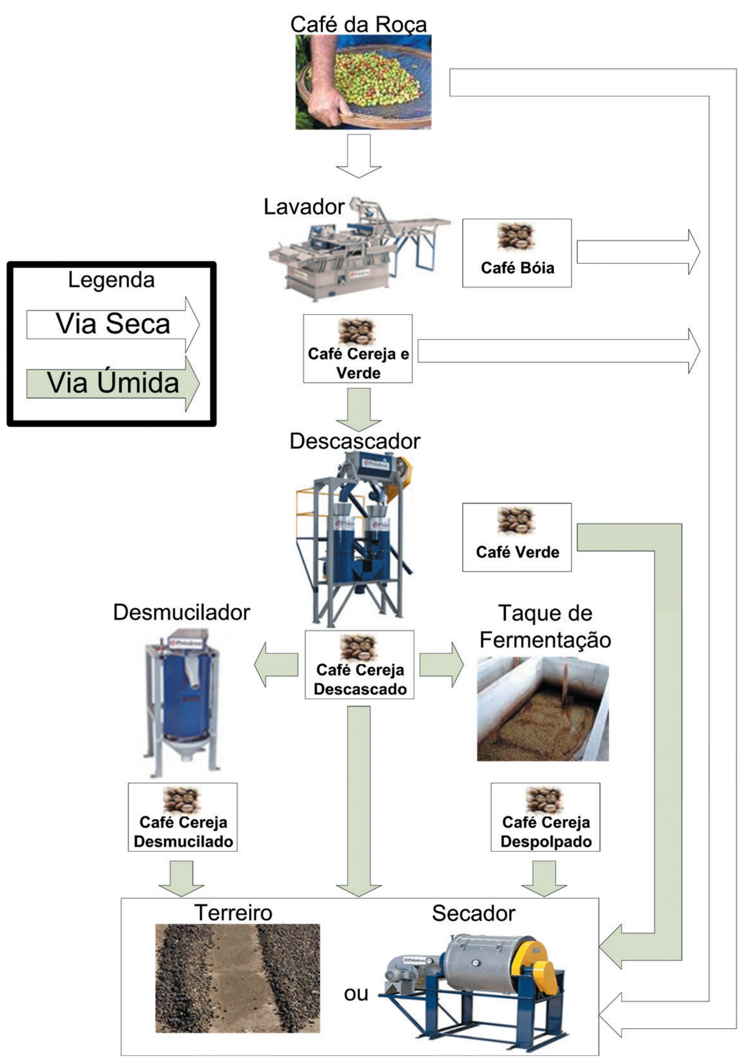


FIGURE 1 - Different possibilities of coffee processing (SANTOS, 2012).

tank, wastewater treatment, thickness of the types of coffee on the patio (meters), drying period of the types of coffee on the patio (days), effective time of drying of the coffee types in the dryer (hours), total time of drying in dryer of the types of coffee (hours), maximum time of operation of agricultural machinery (hours/day), washer, large strainer, peeler, eco-filter, mucilage removing process, spending on buildings, labor for coffee processing, maximum operating time of the dryer (hours/day), dryer, elevator assembly, dryer shed, air heating system, fuel used for drying the coffee.

Implementation of the *Pós-Café* decision support system

The following tools were used in the development of the application:

Programming Language

The programming language chosen for the implementation was Visual Basic.

The main reasons for choosing this language were:

• Easy language: taking into consideration the lack of experience of developers.

• Support for multiple graphic standards: necessary for the results of simulations.

Modeling Language

UML (Unified Modeling Language) was used in the modeling of the *Pós-Café* system, which is a graphic language for visualizing, specifying, constructing and documenting artifacts of complex software systems (BOOCH; RUMBAUGH, 2006).

System modeling was performed using the Rational Rose software (ROSE, 2007).

Database

Access database was chosen. There is no need to install Access (MICROSOF OFFICE, 2010) and its driver on the user's computer, which facilitates the installation of the *Pós-Café*.

Configuration Management

The tool used during project development to support the configuration management was the Apache… (2011). This tool helps organize the files in order to always keep updated versions on all the computers used by developers.

System Verification

Two tests were carried out during the development of the system:

• Tests carried out by system developers: concern checks made by the developers to confirm that the results obtained by the system met requirement specifications.

• Tests carried out by coffee growers: some coffee growers, that can be of assistance in the project, received copies of the *Pós-Café* and were supposed to return them later with suggestions, improvements and possible changes in the system, to ensure that the software achieves the most accurate representation of the post-harvest processing of coffee.

Application of the validation questionnaire to farmers

Thirty-four farmers in southern Minas Gerais answered the questionnaire. These farms were selected because they use several types of processing in coffee plantations. This ensured a more consistent process of validation of the *Pós-Café* system. The information requested in this questionnaire concern the input variables needed to calculate the costs of the post-harvest processing of coffee, which were cited in the previous subsection, in the section Material and Methods.

Table 2 shows the answers provided by the 34 farmers to some input variables. These values were used to simulate the costs of the *Pós-Café* system.

TABLE 1 - Key variables of the costs that were calculated and their respective formulas.

Variable	Formula
Cost of Electricity	(Total Power of Machinery * Value of kWh) / Number of Bags
Cost of Labor in Processing	(Number of Operators of Machines * Price per Day * Time of Harvest) / Amount of Bags
Cost of Labor on the Patio	(Total Number of Workers on the Patio * Price per Day) / Number of Bags
Total Cost of Depreciation	(Cost of Depreciation in Machinery + Cost of Depreciation on Patios) / Number of Bags
Cost of Fuel (This cost takes into account all types of coffee dried)	(Number of Dryers * Effective Drying Time / Total Drying Time) * Harvest Time * 24 * Drying Cost Per Hour) / Number of Bags

TABLE 2 - key data from the questionnaires applied to the 34 farms used in the simulations of costs of the Pós-Café system.

ID	N (%)	B (%)	VE (%)	VD (%)	CV (%)	CD (%)	CDM (%)	SAC (un.)	CO (dias)	kWh (R$)	PMO (R$/ Dia)	MO (un.)	ESP (m)	TT (dias)	TS (horas)	LAV (un.)	DESC (un.)	DESM (un.)	SEC (un.)
1	15.0	55.0	10.0	0.0	0.0	0.0	20.0	19000	80	0.29	30.00	1	0.06	8.00	17.00	1	1	1	2
2	100.0	0.0	0.0	0.0	0.0	0.0	0.0	10000	85	0.29	50.00	0	0.10	6.00-		0	0	0	0
3	16.7	55.0	3.3	0.0	0.0	25.0	0.0	6000	120	0.29	42.00	3	0.03	6.25-		2	2	0	4
4	20.0	45.0	0.0	0.0	35.0	0.0	0.0	4000	60	0.29	50.00	3	0.04	5.00	27.00	1	1	0	2
5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	1700	100	0.29	50.00	1	0.08	10.00-		0	0	0	0
6	100.0	0.0	0.0	0.0	0.0	0.0	0.0	2100	60	0.29	30.00	1	0.05	12.00-		1	0	0	0
7	12.5	51.7	12.5	3.3	0.0	0.0	20.0	6000	90	0.29	50.00	3	0.06	7.00	36.00	1	1	1	4
8	44.0	45.0	0.0	0.0	0.0	0.0	11.0	9000	90	0.29	25.00	3	0.05	5.33	24.00	1	1	1	2
9	10.0	40.0	20.0	0.0	0.0	0.0	30.0	4000	120	0.29	45.00	2	0.05	5.75	25.00	1	1	1	2
10	100.0	0.0	0.0	0.0	0.0	0.0	0.0	900	45	0.15	45.00	1	0.08	9.75-		1	0	0	0
11	100.0	0.0	0.0	0.0	0.0	0.0	0.0	1500	60	0.15	40.00	1	0.10	8.50-		0	0	0	0
12	100.0	0.0	0.0	0.0	0.0	0.0	0.0	4500	70	0.15	45.00	1	0.08	7.50-		0	0	0	0
13	10.0	60.0	0.0	0.0	30.0	0.0	0.0	5000	80	0.26	40.00	1	0.07	7.33	17.50	1	0	0	4
14	100.0	0.0	0.0	0.0	0.0	0.0	0.0	6000	75	0.29	60.00	1	0.08	9.50-		1	0	0	0
15	20.0	63.0	2.5	0.0	0.0	0.0	14.5	13500	60	0.28	40.00	3	0.05	7.63	38.00	1	1	1	8
16	100.0	0.0	0.0	0.0	0.0	0.0	0.0	2300	70	0.15	50.00	1	0.06	9.50-		1	0	0	0
17	100.0	0.0	0.0	0.0	0.0	0.0	0.0	800	26	0.29	50.00	2	0.07	8.00-		1	0	0	0
18	100.0	0.0	0.0	0.0	0.0	0.0	0.0	8000	50	0.18	45.00	2	0.06	8.00-		0	0	0	0
19	100.0	0.0	0.0	0.0	0.0	0.0	0.0	1300	80	0.29	35.00	1	0.17	9.25-		0	0	0	0
20	100.0	0.0	0.0	0.0	0.0	0.0	0.0	8000	105	0.18	45.00	1	0.06	4.25	20.00	1	0	0	4
21	100.0	0.0	0.0	0.0	0.0	0.0	0.0	6500	45	0.15	50.00	1	0.04	8.75	25.00	0	0	0	1
22	100.0	0.0	0.0	0.0	0.0	0.0	0.0	8500	90	0.29	46.00	1	0.06	1.50	24.00	0	0	0	5
23	100.0	0.0	0.0	0.0	0.0	0.0	0.0	3500	95	0.27	30.00	3	0.04	6.00-		1	0	0	1
24	100.0	0.0	0.0	0.0	0.0	0.0	0.0	4700	80	0.29	30.00	1	0.10	9.00-		1	0	0	0
25	100.0	0.0	0.0	0.0	0.0	0.0	0.0	4000	90	0.17	40.00	1	0.13	5.50	12.00	0	0	0	1
26	14.0	55.0	14.0	0.0	0.0	0.0	17.0	18000	120	0.29	40.00	3	0.06	4.00	66.50	2	1	2	9

Continua...

TABLE 2 - Continued.

ID	N (%)	B (%)	VE (%)	VD (%)	CV (%)	CD (%)	CDM (%)	SAC (un.)	CO (dias)	kWh (R$)	PMO (R$/ Dia)	MO (un.)	ESP (m)	TT (dias)	TS (horas)	LAV (un.)	DESC (un.)	DESM (un.)	SEC (un.)
27	0.0	65.0	5.0	0.0	0.0	0.0	30.0	16000	100	0.15	40.00	3	0.06	5.50	40.00	2	2	1	8
28	15.0	45.0	2.0	3.0	0.0	0.0	35.0	6000	90	0.29	50.00	3	0.05	4.40	12.00	1	1	1	3
29	100.0	0.0	0.0	0.0	0.0	0.0	0.0	6000	80	0.29	40.00	1	0.07	6.00	24.00	0	0	0	2
30	20.0	32.0	12.0	0.0	0.0	0.0	36.0	38000	110	0.16	30.00	3	0.02	4.50	17.00	3	5	3	10
31	27.0	17.0	6.0	0.0	0.0	0.0	50.0	6000	72	0.17	45.00	3	0.06	9.17	12.50	2	2	2	4
32	45.0	35.0	5.0	0.0	0.0	0.0	15.0	35000	90	0.19	45.00	3	0.05	9.40	7.67	3	1	1	9
33	15.0	45.0	5.0	0.0	0.0	0.0	35.0	11000	60	0.29	45.00	3	0.10	8.25	19.50	1	1	2	6
34	100.0	0.0	0.0	0.0	0.0	0.0	0.0	1800	100	0.29	50.00	1	0.07	8.50-		1	0	0	0

Legend for the variables in Table 2:
ID: identification number of the selected farm
N: percentage of natural coffee produced
B: percentage of floater coffee produced
VE: percentage of green coffee produced
VD: percentage of peeled green coffee produced
CV: percentage of coffee cherry and green coffee produced
CD: percentage of peeled coffee cherry produced
CDM: percentage of coffee cherry without mucilage produced
SAC: number of coffee bags produced
CO: number of days of the harvest season
kWh: price of the kilowatt-hour
PMO: price of labor per working day
MO: labor used in coffee processing (except the patio labor)
ESP: average thickness of the coffee on the patio (considering all types of coffee produced)
TT: average total drying time on the patio (considering all types of coffee produced)
TS: average total drying time at the dryer oven (considering all types of coffee produced)
LAV: number of washers used in the post-harvest stage of coffee
DESC: number of peelers used in the post-harvest stage of coffee
DESM: number of machines used to remove mucilage in the post-harvest stage of coffee
SEC: number of dryers used in the post-harvest stage of coffee.

Statistical validation of the Pós-Café decision support system

Data from the questionnaire answered by the 34 farmers were used as inputs in simulations processed in the *Pós-Café* system. The proposal was a detailed study of the processing cost reports produced by the system.

A computer software simulation was performed for each one of the 34 farms. These simulations were stored in computer files originated by the functionality of the *Pós-Café* tool, in ".pos" extension. Thus, the simulations can be analyzed at any time.

Data from the 34 questionnaires, as well as the computer software simulations originated by the *Pós-Café* system, were compared to the processing costs informed by the farmers.

After analysis of the data related to processing costs (simulated and informed by the farmers) and verification of the normal distribution and homogeneous variance, statistical analysis was proposed for validation of the *Pós-Café* tool, which included parametric test with comparisons of means, specifically Student's t-test.

3 RESULTS AND DISCUSSION

Pós-Café Support Decision System

The *Pós-Café* consists of a support system aimed to facilitate decision making regarding the most cost-effective post-harvest processes, that is, it uses human knowledge to solve problems that require the presence of a specialist in this stage of coffee processing.

The main contribution of the *Pós-Café*, from the modeling and systematization of this knowledge, is to facilitate the decision making by growers, cooperatives and consultants regarding the most cost-effective processes to be used during the post-harvest stage of coffee. Such decision making would be facilitated by greater knowledge of the costs of separation, peeling, pulping, mucilage removal and drying processes, as well as of the revenues generated by the sale of the coffees produced after the application of these processes.

The basic idea of the system is to enable the user to choose two possible coffee processing systems, as shown in Figure 2, in order to carry out a simulation of costs and comparison of the two processes.

After the selection of the type of processing, the user must provide data related to production, according to some forms of data entry (Figure 3).

The *Pós-Café* system shall process and return the reports of processing revenues (Figure 4), processing costs (Figure 5) and net margin (Figure 6).

The decision of the coffee grower on the best process to be adopted shall be facilitated by the information reports generated by the system:

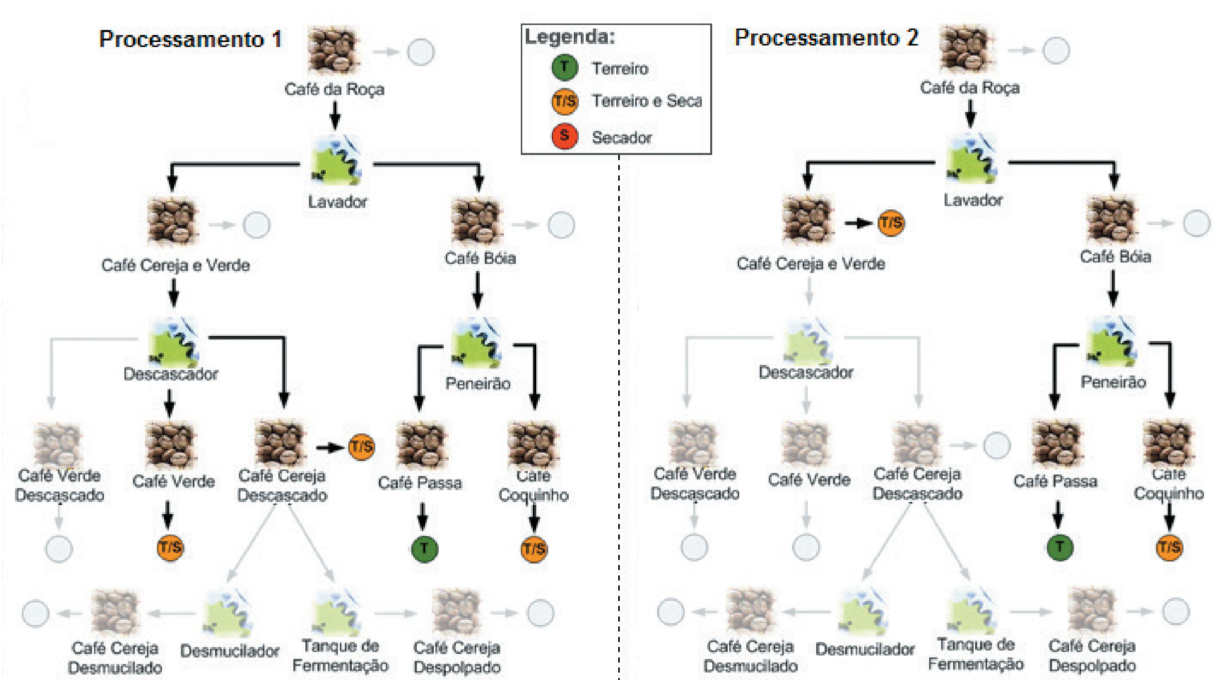


FIGURE 2 - Screen for selection of coffee processes of the Pós-Café tool (SANTOS, 2012).

• Revenue report (Figure 4): This report presents the total number of bags produced for the types of coffee selected for the processing chosen. The values in reais (R$) of each bag and the total revenue are also shown for each type of coffee.

• Cost report (Figure 5): This report presents the cost per bag, in reais (R$), sorted by categories of electricity, labor in coffee processing (operators of agricultural machinery), labor on the patio (workers that turn the coffee on the patio), total depreciation (depreciation of the patio and agricultural machinery) and the cost of fuel (used in mechanical drying of coffee).

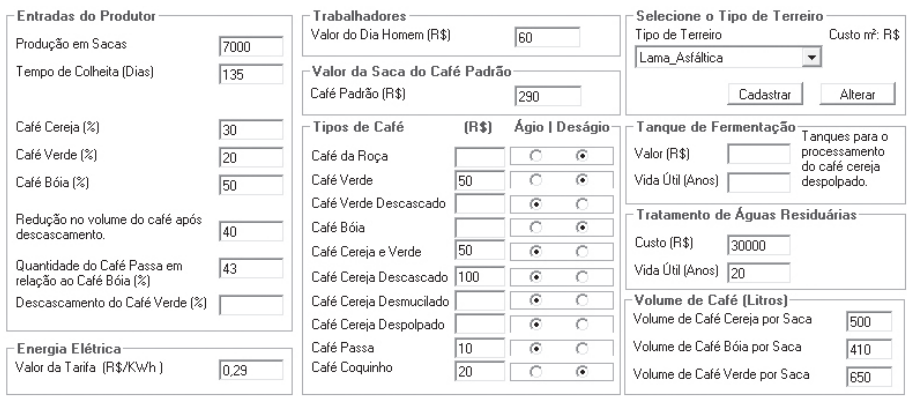
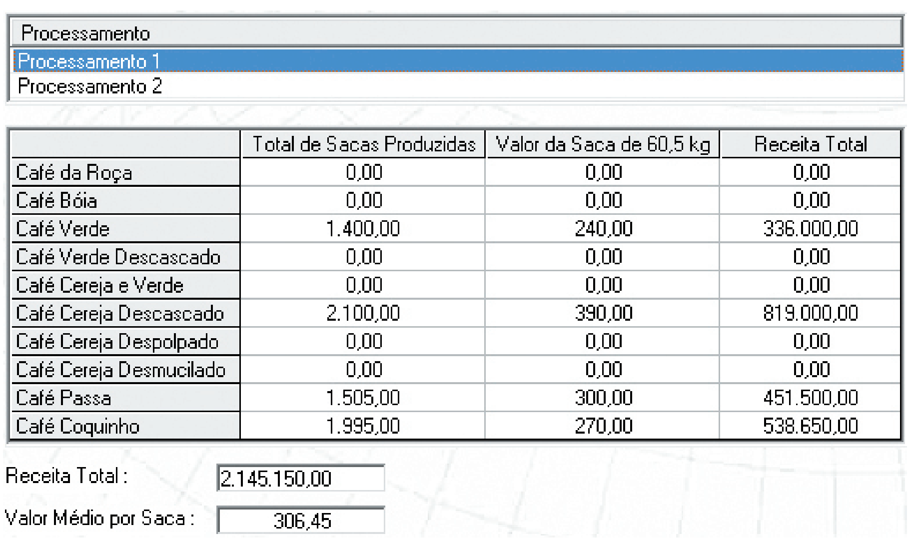


FIGURE 3 - Data entry screen of the Pós-Café tool (SANTOS, 2012).



	Total de Sacas Produzidas	Valor da Saca de 60,5 kg	Receita Total
Café da Roça	0,00	0,00	0,00
Café Bóia	0,00	0,00	0,00
Café Verde	1.400,00	240,00	336.000,00
Café Verde Descascado	0,00	0,00	0,00
Café Cereja e Verde	0,00	0,00	0,00
Café Cereja Descascado	2.100,00	390,00	819.000,00
Café Cereja Despolpado	0,00	0,00	0,00
Café Cereja Desmucilado	0,00	0,00	0,00
Café Passa	1.505,00	300,00	451.500,00
Café Coquinho	1.995,00	270,00	538.650,00

FIGURE 4 - Screen of the report of the revenues from Pós-Café processes (SANTOS, 2012).

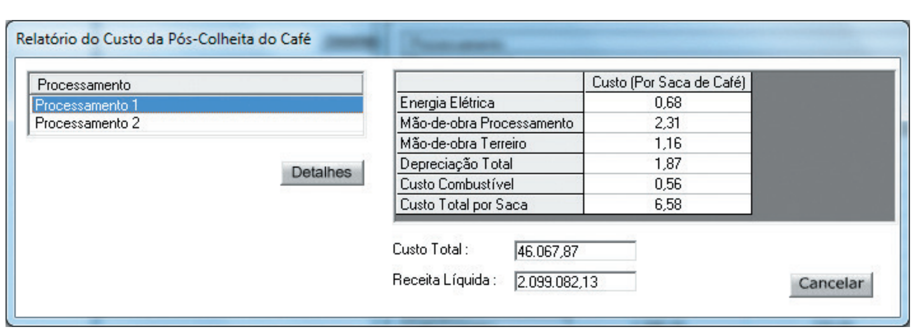


FIGURE 5 - Screen of the report of Pós-Café processing costs (SANTOS, 2012).

• Net margin report (Figure 6): This report presents the cash value per coffee bag that the grower will gain or lose depending on the type of coffee processing chosen. In the example of Figure 6 the grower will lose sixty cents if processing one (1) is chosen instead of processing two (2).

All reports shown above (reports of net revenue, processing costs and net margin) take into account the percentage values of coffee cherry, percentage of green coffee, premium and discount of coffee bags informed in the data input forms. (Figure 3).

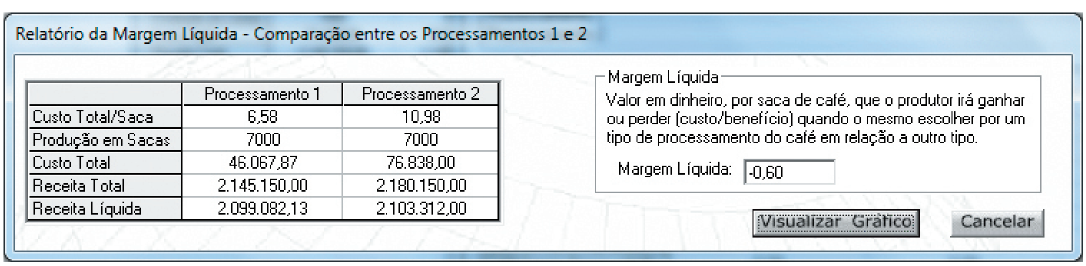
However, Figure 7 shows a graph of the net margin generated by the *Pós-Café* tool.

In the net margin graph, the grower can visualize other situations that consider different premiums (value in reais for the difference between bags of the type of coffee of higher value of each processing) and percentages of coffee cherry (percentage of coffee cherry at the time of harvest).

Speculating on these aspects, the grower can identify at what point one processing is economically more advantageous than the other.

In Figure 7, the point 30% of coffee cherry and 50 reais of premium is stressed, which represents the difference between the coffee bags with higher value for processing number one (bag of peeled coffee cherry: R$390,00) and processing number two (bag of coffee cherry and green: R$340,00). At this point, the net margin is approximately minus sixty cents of real (-0.60). That is, choosing processing number one (1) instead of processing number two (2), under these conditions, will cause the grower to lose sixty cents of real (-0.60) per bag of coffee produced. Under different conditions, e.g. the point 40% of coffee cherry and 60 reais of premium, processing number one (1) is preferable over processing number two (2).

In short, the graph is a resource of the tool that simulates new situations to assist the coffee grower in making decisions.


Relatório da Margem Líquida - Comparação entre os Processamentos 1 e 2

	Processamento 1	Processamento 2
Custo Total/Saca	6,58	10,98
Produção em Sacas	7000	7000
Custo Total	46.067,87	76.838,00
Receita Total	2.145.150,00	2.180.150,00
Receita Líquida	2.099.082,13	2.103.312,00

Margem Líquida
Valor em dinheiro, por saca de café, que o produtor irá ganhar ou perder (custo/benefício) quando o mesmo escolher por um tipo de processamento do café em relação a outro tipo.
Margem Líquida: -0,60
Visualizar Gráfico
Cancelar

FIGURE 6 - Report of the report of net margin between the Pós-Café processes (SANTOS, 2012).

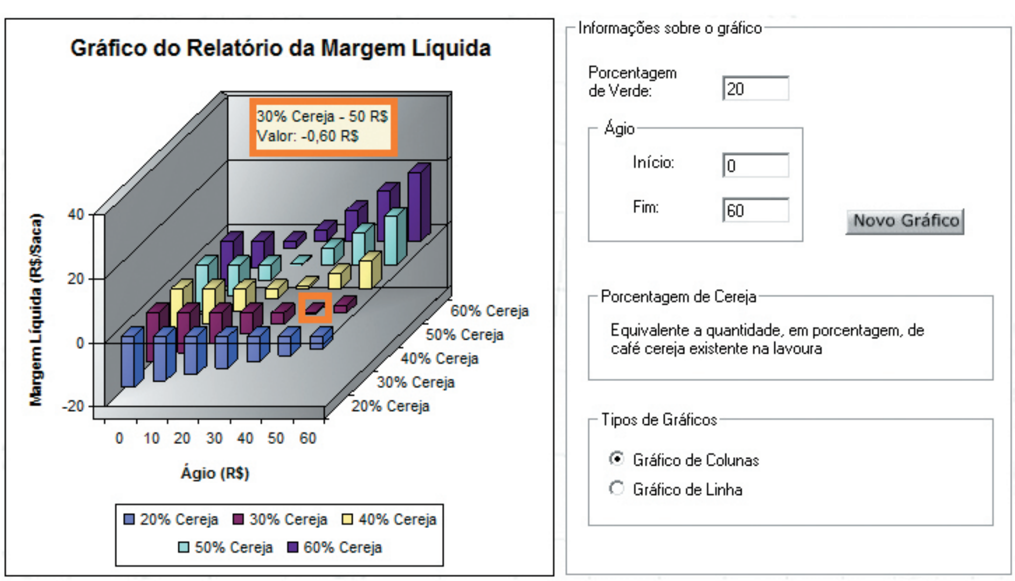


FIGURE 7 - Screen of the net margin graph for the Pós-Café tool (SANTOS, 2012).

Statistical validation of the *Pós-Café* decision support system

For the validation of the *Pós-Café* system the costs per bag of coffee during the post-harvest stage reported by the farmers were compared to the costs simulated in the *Pós-Café* system, with the answers to the questionnaires provided by these farmers considered as input data.

So the statistical validation of the *Pós-Café* tool considered cost data reported and simulated from the 34 farms, as shown in Table 3.

Student's t-test was used for statistical validation. The t test is applied to test hypotheses of population means when variables are normally distributed variables with unknown variances.

TABLE 3 - Data from informed and simulated costs of farms in southern Minas Gerais.

Farm	Informed Cost	Simulated Cost
1	R$ 6.00	R$ 6.98
2	R$ 2.10	R$ 4.08
3	R$ 9.00	R$ 8.66
4	R$ 15.00	R$ 11.82
5	R$ 6.00	R$ 9.36
6	R$ 15.00	R$ 7.76
7	R$ 20.00	R$ 17.72
8	R$ 8.50	R$ 8.04
9	R$ 10.00	R$ 11.17
10	R$ 12.22	R$ 8.59
11	R$ 8.45	R$ 5.24
12	R$ 8.50	R$ 8.35
13	R$ 12.00	R$ 9.61
14	R$ 7.15	R$ 10.00
15	R$ 6.00	R$ 8.98
16	R$ 10.04	R$ 8.13
17	R$ 13.02	R$ 9.32
18	R$ 10.30	R$ 10.20
19	R$ 7.00	R$ 7.01
20	R$ 6.00	R$ 6.95
21	R$ 4.00	R$ 8.55
22	R$ 5.00	R$ 9.27
23	R$ 5.80	R$ 6.05
24	R$ 2.50	R$ 4.54
25	R$ 8.00	R$ 5.25
26	R$ 9.50	R$ 14.16
27	R$ 9.50	R$ 9.41
28	R$ 8.80	R$ 9.39
29	R$ 8.00	R$ 10.85
30	R$ 8.00	R$ 6.92
31	R$ 12.00	R$ 11.69
32	R$ 10.00	R$ 9.25
33	R$ 10.00	R$ 9.36
34	R$ 10.00	R$ 15.24

According to Ribeiro and Melo (2009), this is a case of two dependent populations, and, thus, the random variable of interest was the difference between the pairs of two samples, instead of the values of these samples that must have the same size.

Table 4 shows information related to the descriptive statistics analysis of cost data.

After descriptive statistics, the *Lilliefords* test was conducted to test data normality, according to Table 5.

Conclusion: as the calculated value (0.0746) is lower than the tabulated values (α = 0.05 and α = 0.01), hypothesis H_0 is not rejected. Therefore, the random variable D has a normal distribution.

Once data normality is verified, Student's t-test (Table 6) was applied with the purpose of comparison of means. The hypotheses tested were: H_0 (μ_D=0) vs H_a ($\mu_D \neq 0$), where D represents the difference between the two populations.

Conclusion: it can be seen that average difference was equal to zero (P=0.7842 > α=0.05). Thus, there is no difference between the means of variables Y1 and Y2.

TABLE 4 - Descriptive statistics of data related to processing costs.

Variables	Minimum	Maximum	Missing	Valid
REP	1.0	34.0	0	34
Y1	2.10	20.0	0	34
Y2	4.08	17.7	0	34

Y1 = Informed Processing Costs
Y2 = Simulated Processing Costs
D = Y1-Y2 = Difference between Informed and Simulated Processing Costs.

TABLE 5 - Verification of normality.

Variables	Calculated Value	Value (P=0.05)	Value (P=0.01)
D	0.0746	0.152	0.177

TABLE 6 - Student's t-test for comparing the means

Variables	Data	Means	Deviations	T	GL	Probability
Y1		8.9229	3.6222			
D	34	-0.1329	2.8073	-0.276	33	0.7842
Y2		9.0559	2.8611			

4 CONCLUSIONS

The *Pós-Café* decision support system has proven to be a reliable tool. The costs of coffee processing in the post-harvest stage calculated by the *Pós-Café* are consistent with the costs informed by the farmers.

The *Pós-Café* tool can be used by coffee growers, consultants and other professionals involved in the post-harvest stage of coffee to help them make decisions regarding the most cost-effective processes to be used during the referred stage.

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