Journal of Bioenergy and Food Science

J. Bioen. Food Sci, 02 (2): 55-61, 2015

Journal homepage: http://periodicos.ifap.edu.br/index.php/JBFS

ISSN 2359-2710

Scientific article

Mapping dairy plants and location strategies for whey processing in Rio de Janeiro, Brazil

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ARTICLE INF.

Received: 10/23/2014

Accepted: 04/22/2015

Published: *06*/05/2015

DOI

10.18607/jbfs.v2.i.2.11

Index terms:

Cheese whey

Whey processing plant

Rio de Janeiro state

Mathematical model.

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ABSTRACT

The objective of this study was to assess the technical and economic feasibility of the use of whey resulting from the cheese making process in the State of Rio de Janeiro. Data was collected from 52 dairy plants that produce or buy whey, by means of questionnaires. Based on the data obtained, a mathematical model for the location of processing plants was built, considering production logistics, sample collection, regions with potential to locate whey processing plants and possible areas of environmental impact from cheese industries. Whey processing was more concentrated in the south of the state of Rio de Janeiro, with 59.5% during the season, and 58.4% in the off-season period. The production in the season and off-season periods was stable, with good distribution throughout the State. Only 30.7% of the total whey generated was used by industries to produce dairy beverages and ricotta, and 70.3% was discarded. According to the present study, the ideal solution for the use of whey in the referred region, should consider the establishment of two processing plants and the definition of strategic convergence points (whey drying facilities, in Macuco and Valença), and the subsequent transport of the products for final processing.

Mapeamento das indústrias laticinistas e estratégicas locacionais de processamento de soro no Rio de Janeiro, Brasil

Objetivou-se estudar a viabilidade técnica e econômica do aproveitamento do soro de queijo produzido no Estado do Rio de Janeiro, a partir da realização de questionários em 52 estabelecimentos de cinco regiões do Estado que produzem ou compram soro. A partir dos dados, determinou-se um modelo matemático de localização de plantas de processamento reunindo as questões de logística de produção e coleta de soro, identificando regiões com potencial de plantas processadoras de soro, além de caracterizar áreas de possível impacto ambiental da indústria queijeira. O processamento de soro de queijo no Estado concentrou-se mais na Região Sul do Estado, com 59,5% na safra e 58,4% na entressafra. A produção na safra e entressafra foi estável e com boa distribuição por todo o Estado. Somente 30,7% da produção total eram reaproveitados dentro das indústrias na produção de bebida láctea e ricota. Conclui-se que a formação de uma cadeia de aproveitamento do soro de queijo deve ser constituída de dois pontos para o beneficiamento final do soro (secagem e/ou produção de concentrado proteico de soro e de permeado de lactose) em Macuco e Valença.

Termos de indexação: Soro de queijo; plantas de processamento de soro de queijo; estado do Rio de Janeiro, modelo matemático.

Funding: The authors report support and funding in the work done by the FAPERJ (Foundation for support of research in the State of Rio de Janeiro), Brazil. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Competing interests: The authors have declared that no competing interests exist.

How to refer to this document (ABNT):

CORTEZ, N. M. S.; ZOCCAL, R.;.LEITE, J. L. B.; DIAS, J.; CORTEZ, A. S. Mapping dairy plants and locations strategies for whey processing in Rio de Janeiro, Brazil. **Journal of Bioenergy and Food Science,** Macapá, v.2, n. 2, p. 55-61, abr./jun.. 2015. http://dx.doi.org/10.18607/jbfs.v2.i.2.11

INTRODUCTION

The cheese production in Brazil was 721,411 tons in 2009, an increase of 7.8% compared to 2008. It is estimated that the cheese production of 2008 generated approximately 12 million liters of whey (EMBRAPA, 2012).

Brazil imported 36.2 thousand tons of whey powder in 2008. These figures highlight the existence of an attractive market for the use of whey, considering only import substitution (EMBRAPA, 2012). Whey has great biological value compared to other nutrient sources (GERDES et al., 2009). It has a high content of branched side chain amino acids (isoleucine, leucine and valine) compared to other protein sources (SINHÁ et al., 2007).

Whey has a wide range of applications in the food and pharmaceutical industries (SOUZA, 2004; CHENG et al., 2005), due to its functional properties emulsifying and foaming properties, gelling ability, viscosity and solubility, being used in beverages, dairy and meat products, confectionery, soups, condiments and dietetic products (SINHÁ et al., 2007). Experiments demonstrate the benefits of the use of concentrated whey in the preparation of cheeses, obtaining desirable coagulation and products with characteristics similar to those of traditional manufacture (COSTA JÚNIOR, 2006; FLORENTINO, 2005; SILVEIRA et al., 2009, PAULA et al., 2012).

In addition to the spatial dispersion, cheese production is characterized by two different basic structures: industrial, modern scale that uses international quality standards and a small scale, handicraft production that does not count on well-defined standards. The latter is widespread in the region and the whey produced (with a low commercial value as a fresh product and high cost of collection) is usually treated as waste and discharged to rivers without prior treatment, causing environmental impact (CHEHADI & VIEIRA, 2004). However, there is scarce information on the location and availability of industrial units in Brazil. The use of secondary data from the national statistics (IBGE, 2008) and the search for indicators of the high correlation with the studied variables are appropriate alternative techniques in the absence of a stable and continuous of agricultural production statistics.

In Minas Gerais, Brazil's biggest producer of cheese, studies on the logistics of whey collection (ALVES, 2005) used information of the Federal Inspection System of the Ministry of Agriculture, Livestock and Supply. The concentration index of milk production of a given micro-region (ZOCCAL et al., 2006) can be a reliable indicator of the production potential. Production mapping by means of geo-processing techniques guide prospective studies on the concentration of cheese production.

Due to the high added value of cheese whey, an economically viable alternative was chosen for production flow, namely: the use of two strategically located facilities for pre-concentration and final processing (drying) of whey, which may be the ultimate solution for the issue of the appropriate use of whey. (ROHLFES et al., 2011).

Logistics problems are also defined as multiple constraint problems, such as business hours; capacities of the vehicles; fleet of vehicles of different sizes; maximum duration of the itineraries of the vehicles; restrictions on some types of vehicles for some clients or products and characteristics of the different products to be transported (LAPORTE et al., 2000).

In order to systematize the theoretical frame, Haddad et al. (1989) suggested a classification of the location factors, to provide the basis for the e entire subsequent analysis. The characteristics of the productive process present two dichotomies (input and product) and the spatial dimension of reference (local and transferable). For each decision on location, the costs and benefits of a given location should be weighed. This procedure allows defining the relative importance of the location factors.

The present study aimed to map and locate the industries that produce and/or process cheese whey in the State of Rio de Janeiro, establish strategic locations of whey processing industries and suggest techniques for the rational use of the product.

MATERIAL AND METHODS

The *Instituto de Assistência Técnica e Extensão do Estado do Rio de Janeiro* - EMATER RIO- (Agricultural Extension Agency - Rio de Janeiro) assisted in the data collection for the present research. The study consisted initially in the division of the State of Rio de Janeiro in five regions: Northwest, Mountain, Northern Central and Southern. Information regarding the number of establishments that produced cheese whey in each region was obtained: there were 52 collection points. The technical visits to the establishments were scheduled between the months of June and November 2009. A questionnaire was completed by the representatives in all these establishments.

The use of the data obtained in the questionnaires provided the basis for the construction of a mathematical model of location of processing plants, which comprised collection logistics issues, according to Leite (2005). The basic assumptions of the model were established, as follows:

i. Small sized dairy plants are interested in selling the cheese whey generated;

ii. The daily collection of why in appropriate transportation means (truck) (capacity of 25-30 thousand liters);
iii. Collection performed in cities that produce more than 3,500 liters of whey/day;
iv. The whey produced in several establishments in the same city was considered local production;
v. The price for whey collection was R$ 0.08/1.000 liters/km, according to research information.

With the use of Microsoft Excel Solver, three simulations were conducted: number 1, with five collection points; number 2, with three collection points and number 3, only one final collection point.

The function is the cost of whey collection logistics with the mathematical expression:

Minimum collection cost: $Min\ C_{cs}^{n} = \sum_{m=1}^{t} Qt_{m}^{n}\ x\ D_{m}^{n}\ x\ Pts$

Considering that: $m = n \rightarrow D_{m}^{n} = 0$

Subjected to: $\sum_{m=1}^{t} Qt_{m}^{n} = Q_{m}$

Eq. (1)

Where:
C_{cs}^{n} – total cost of whey collection for city "n";
$\mathrm{Qt_m^n}$ – total amount of whey transported from city "m" to city "n"
Qt^{n} – total amount of whey collected in the city "n" available for processing;
$\mathrm{Qt_m}$ – amount of whey produced in the city "m";
D_{m}^{n} – distance in km between city "m" and city "n";
Pts – price of whey transport (R$/liter/km).

Given the existence of a high number of whey-based dairy products (ricotta, milk beverages of various flavors, protein concentrates, among others), the productive chain should be optimized considering, in addition to logistic costs, the production costs for each whey-based product developed and their market prices. Thus, the processing technology for each whey-based product would give the amount of whey necessary for product unit weight, and then the maximum amount that could be obtained for each product would be known. Based on the production costs, on how much can be produced with the collected whey and the market prices it is possible to simulate optimum product portfolios. Therefore, the following mathematical expression would be used:

Maximize the profit of the whey processing plant

$$\mathrm{Max\ L_n} = \sum_{\mathrm{px=1}}^{\mathrm{y}} \{\mathrm{Pm_{px}} - (\sum_{\mathrm{tec=1}}^{\mathrm{z}} [(\mathrm{C_{cs}^{n}} \div \mathrm{Qt^{n}}) \times \mathrm{Qs_{px}^{tec}}) + (\mathrm{Qs_{px}^{tec}} \times \mathrm{Ps}) + \mathrm{O_{px}^{tec}}])\} \times \mathrm{Q_{px}}$$

Eq. (2)

Considering:

$$\sum_{px=1}^{y} \frac{Q_{px}}{Qs_{px}^{tec}} \leq Qt^{n}$$

Where:

$\mathrm{L_n}$ – Maximum profit of the processing plant located in the city "n";
Ps – Price of raw material whey;
$\mathrm{Q_{px}}$ – Amount of product "px" sold in the market; indicates the optimum "mix" for the processing plant;
$\mathrm{Pm_{px}}$ – Market price of the product "px";
$\mathrm{Qs_{px}^{tec}}$ – Amount of whey used in the production of one unit of "px", depending on the technology (tec) used;
$\mathrm{O_{px}^{tec}}$ – Other production costs of "px".

Considering the technology used, these are fixed costs, including labor costs, energy, other inputs, packaging and transport costs related to the distribution of the finished products, taxes and depreciations.

Results and discussion

More than half of the points with capacity of processing whey from the cheese making process in the State of Rio de Janeiro are concentrated in the

southern region. These points are distributed as follows: 59.5% during the season (**Figure 1**) and 58.4% in the off-season period (**Figure 2**), and their shares were 11-15% in the mountain and northern regions, and 7-9% in the northwest and central regions.

Most plants visited (84.6%) have been selling their products in the marketplace for more than six years, having considerable experience in the sector. This factor favors the maintenance of the chain of whey use, if economically feasible. Analysis of data from SEBRAE (2012) shows increase in cheese production throughout the Brazilian territory, which leads to the increase in the production of whey, and consequently, in the profits of the cheese and related industries.

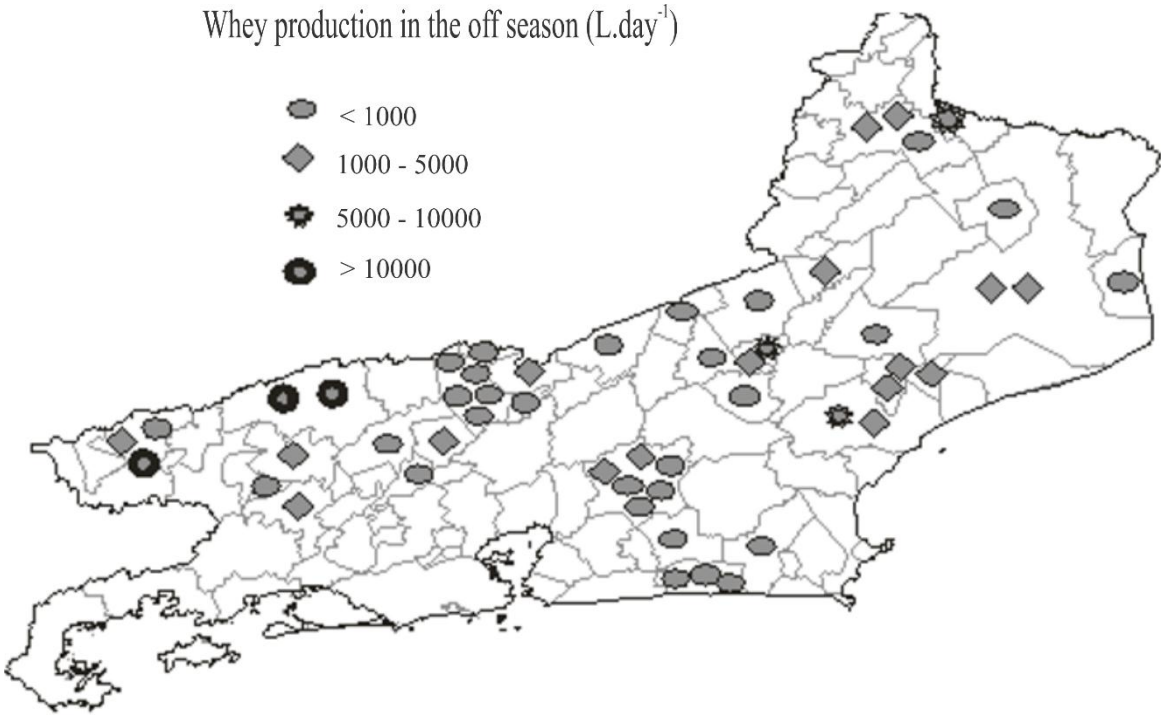

Figure 1. Average production of whey from cheese making (liters) in dairy plants in the State of Rio de Janeiro during the season (October to April), in 2009.

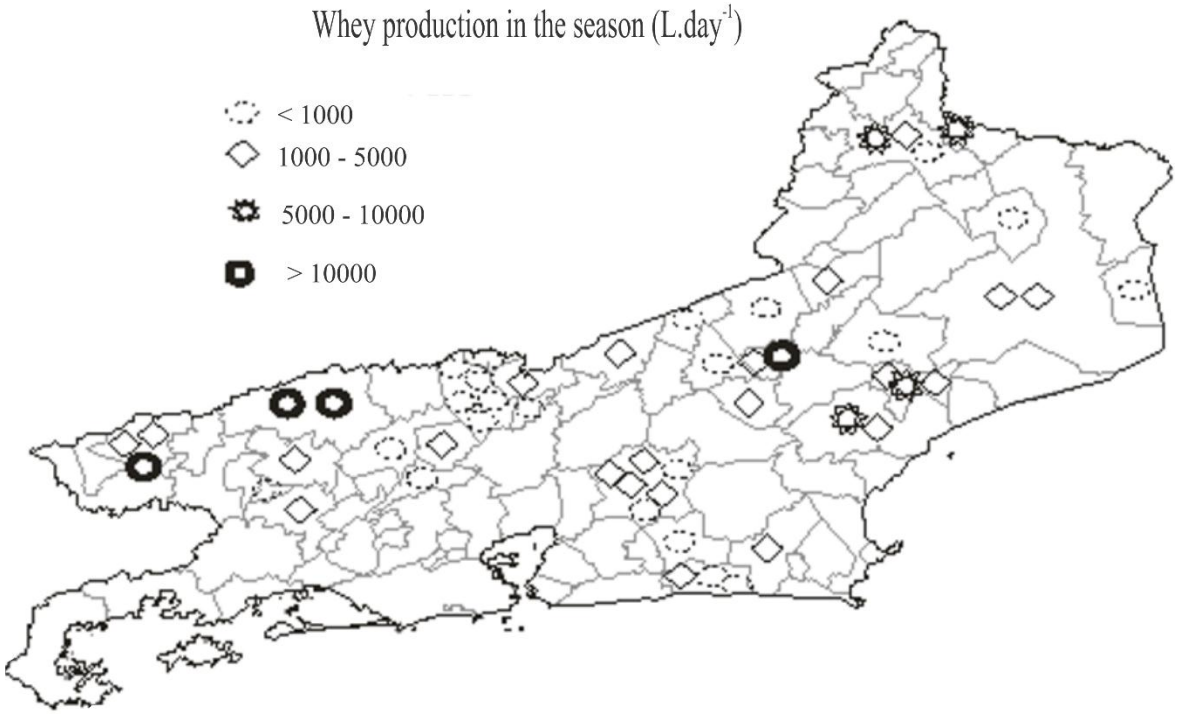

Figure 2: Average daily production of whey resulting from cheese making (liters) from dairy plants in the State of Rio de Janeiro during the season (May to September), in 2009.

A percentage change (**Figure 3**) was observed in the production of whey comparing the season and off-season periods in the dairy plants of the State of Rio de Janeiro. However, a steady and manageable production of whey was also observed throughout the State, ensuring a constant flow to the processing facilities. This is consistent with the study conducted by Silveira & Freitas (2011) who reported a higher production in the season period compared to the off-season period.

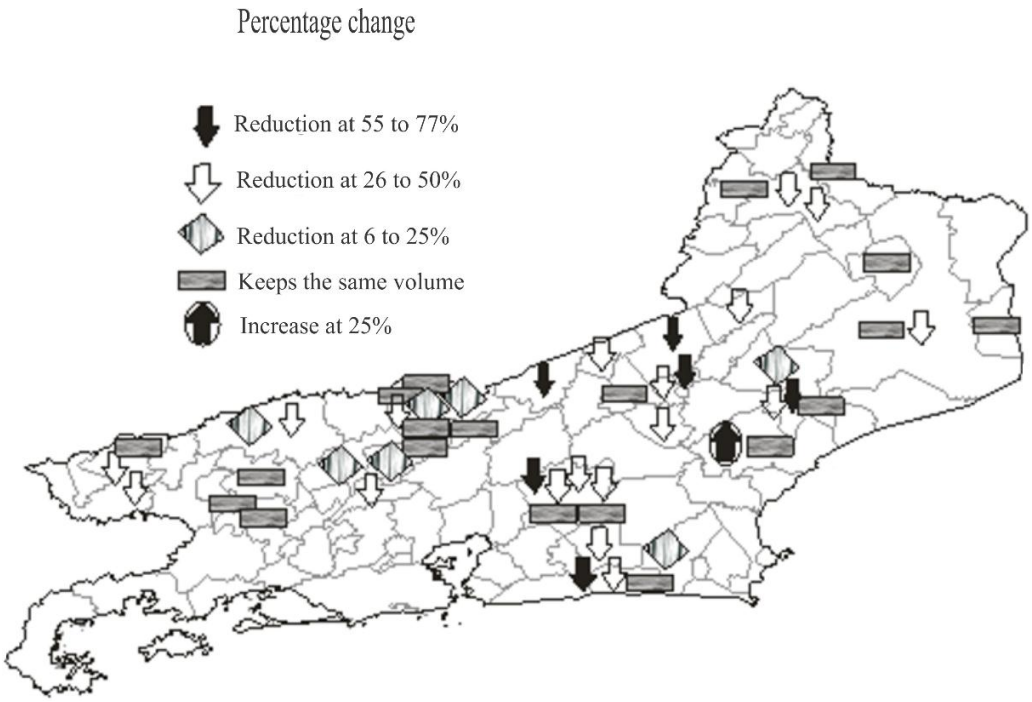

Figure 3: Percentage change in the production of whey from cheese making between the season and off-season periods in dairy plants of the State of Rio de Janeiro, in 2009.

Most plants (41.3%) were inspected by the State authorities. Regarding Federal and Municipal inspections, they were performed in the same percentage of dairy plants (23.1%), ensuring greater security to the products made from whey processed in these plants. In a small percentage of plants no type of technical inspection was performed (10%). Only nine (17.3%) had some sort of Quality Control Program

Of the 52 plants visited, only seven (13.5%) did not produce sweet whey and 12 (23.1%) produced both sweet and acid whey. None of the dairy plants purchased whey from third parties. Thus, there were no suppliers, and no type of contract. The discarded whey was not analyzed for determination of its composition or quality. Up to the moment of its collection by third parties, the whey was stored in fiber glass tanks (40.3%), plastic containers (17.3%) or milk cans (11.5%). Only 7.7% were kept in insulated tanks, and the remaining 23.2% were maintained in other types of containers. The latter were immediately processed or used for animal feed.

A similar situation related to whey storage was reported in the study of Nogueira et al. (2011) in a dairy plant in the region of Lavras-MG, where the product was placed in a tank from which it was pumped for use in animal feed. The tank was maintained open and sometimes overflowed with the excess production discharged in the water causing direct environmental contamination.

In the study of Silveira & Freitas (2011) the whey produced in a plant in the State of Bahia was not subjected to waste treatment, was stored in masonry tank and used in animal feed.

In this study, the total whey resulting from cheese making in the State of Rio de Janeiro generated 4,114 tons per month, and 30.7% (1,267 tons) were industrially processed in the production of ricotta (78%), UHT milk products (18%) or fermented milk beverages (4%).

Thus, 2,847 tons/month of whey from the cheese process were sent to Minas Gerais after concentration (1,200 tons), sold (295 tons) or freely distributed to cooperative members or local farmers (1,352 tons). The reported sale price of whey ranged from R$ 0.01 to R$ 0.15, and the product was used for feeding bovines and swines, and this tendency was also reported by Silveira & Freitas (2011). Only one farm used whey as an organic compound constituent.

The variable costs related to the distance traveled, the fixed costs of the vehicles and the hourly costs of the operational team (including the decision of requiring or not overtime from the team to reduce

the number of vehicles and the mileage traveled) should also be considered. The definition of the routes, the use of the most advantageous transport (own fleet of vehicles or outsourcing) to minimize the total costs is another aspect to be considered due to the peculiarities of the Brazilian reality.

According to Laporte et. al (2000), the definition of the routes for transport of whey-based products involves the use of vehicles that minimize the total cost of transport, ensuring that each point is visited once and that the demand does not exceed the capacity of the vehicle.

The use of whey in high added value products requires considerably large investments, which demand significant volumes of whey. In a dispersed production structure, whey collection and transport to a processing unit is essential.

The results obtained for the simulations of processing capacity were as follows: For simulation no 1, the model was structured through the variable "controller" to obtain a number of processing cities "n" equal to five. According to the results, it was concluded that the eligible cities were:

a) Itaperuna (25,900 liters/day), which in addition to the 13,900 liters generated in the city would receive 12,000 liters from Bom Jesus de Itabapoana;
b) Conceição de Macabu (31,600 liters/day) that in addition to the 15,700 liters generated locally would receive 9,900 liters from Campos and 6,000 from Cordeiro;
c) Resende (54,200 liters/day) that would process its own production;
d) Macuco (71,400 liters/day), that in addition to the 24,900 liters generated in the city would receive 20,000 liters from Cachoeira do Macacu, 4,500 liters from Itaocara and 22,000 liters from Macaé; and
e) Valença (134,500 liters/day), that in addition to the 125,000 local liters would receive 6,000 liters from Barra do Pirai and 3,500 liters from Paty de Alferes. The total volume to be transported would be 317,600 liters/day at a total cost of R$ 548,00.

In simulation no 2, the model was structured using the variable "controller" to obtain a number of processing cities "n" equal to three. According to the results obtained, it was concluded that the eligible cities were: (a) Resende (54,200 liters/day), because of the locally generated volume; (b) Macuco (128,900 liters/day); and (c) Valença (134,500). The total volume transported would be 317,600 liters/day at a total cost of R$ 931,09. According to this result, the city of Macuco received the highest volume of whey transported. Thus, in a possible expansion of the production of cheese in the several establishments of the cities of the State of Rio de Janeiro, Macuco would provide greater advantages in terms of whey collection, storage and processing. Simulation no 3. The model was structured using the variable "controller" to obtain a number of processing cities "n" equal to one. The result indicated that the eligible city is Valença, at a total cost of R$ 3.525,00. This finding was strongly influenced by the amount of whey generated in the city and the assumption of zero cost of transport within the city itself.

It can be inferred from the above simulations that, if two cities should be selected for concentrating the whey processed in the State of Rio de Janeiro, these would be Valença and Macuco. The whey generated in Resende should be transported to Valença because of the shorter distance between the cities. Thus, Valença would process 188,700 liters and Macuco 128,900 liters. The costs would be increased only by R$ 489,97 compared to simulation no. 2. This increase is produced by the cost of transport of whey from Resende to Valença (R$ 489,97), reaching a total value of R$ 1.421,06/ day for gathering the total amount of whey in the State in only two cites, which would represent a cost reduction of de 40% compared to the cost of using only one place (city).

From the point of view of mathematical modeling, this type of result is quite complex because there are no fast and accurate solution algorithms that consider all these variables. Therefore, the solutions adopted by heuristic algorithms (not optimizers from a mathematical view, but which produce almost optimal solutions), as well as the research and development of solutions and technologies in the field of geo-information, enable a more realistic representation of the complex problems of physical distribution in everyday life (ROSSETTO, 2008).

According to Ferreira Filho (2001), the Vehicle Routing and Programming Systems are computer systems that, by means of generally heuristic algorithms and an appropriate database, can obtain solutions for vehicle routing and programming with relatively satisfactory results, consuming less processing time and effort.

Conclusions

Based on the mapping conducted here it is concluded that most of the whey produced in the State of Rio de Janeiro is used in animal feeding, and some industries used whey in the production of milk beverages and ricotta. In order to ensure a rational use of whey, two strategic points located in the cities of Macuco and Valença were found to have technical and economic feasibility for the collection of liquid whey and final processing by drying and/or production of whey protein concentrate.

Acknowledgments

To the team of EMATER-RIO and PESAGRO-RIO for the field research in the collection of samples and data from the questionnaires. To FAPERJ for project approval and financial support in the development of the study.

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