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Supporting small-scale dairy plants in selecting market opportunities and milk payment systems using a spreadsheet model

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A B S T R A C T

Simulation tools can be helpful for supporting stakeholders in better planning and managing dairy supply chains and exploring alternative ways of organizing chains. This paper presents a support approach dealing with two strategic issues that dairy processors face in interactions with their suppliers and buyers: (i) selecting their product portfolio according to market opportunities and (ii) designing milk payment systems encouraging dairy farmers to supply good quantity and quality milk throughout the year. This approach is based on the design of a spreadsheet application called DairyPlant developed with Excel®. DairyPlant calculates the daily profit obtained by a dairy processing unit and the gross revenue obtained by each of its suppliers according to its product portfolio, its milk payment system and its suppliers' individual milk quantity and quality profile. Calculations take into account the processing yield defined by the software user for each marketed and intermediate product. Payment systems may include a base price and up to three quality components. The approach was tested in two small-scale dairy plants in the Mantaro Valley (Peru). For each plant, this included technical and economic data collection, construction of a reference scenario closed to the current plant situation, and simulation and evaluation of alternative portfolios or milk payment systems. Based on these simulations, dairy processors realized that (i) they could increase their total profits by modification of their current portfolio toward higher value products on the assumption that milk delivered to the plant attained a given quality; (ii) they did not adequately compensate farmers who delivered good quality milk but overpaid some who delivered poor quality milk; (iii) their profits could be increased by adoption of a payment system based on milk quality. Advantages and limits of DairyPlant are discussed in the light of an extended use of the support approach in other locations.

1. Introduction

In both developing and developed countries small-scale firms dominate in the agricultural sector (Nichter and Goldmark, 2009). They generally have difficulties in satisfying high-value agro food market requirements (Henson and Reardon, 2005; Kirsten and Sartorius, 2002), while using their technological assets in a cost effective way (Cuevas, 2004). In developing countries, the lack of managerial ability and of knowledge on processing techniques also impact on stakeholders' performances and usually result in small-scale firms' inefficiency and also higher costs (Li, 2012). The dairy sector also has similar problems due to limited control of milk quality along the chain, the risks of late processors' payments to farmers, and few processor incentives to encourage farmers to produce good milk quality. This general context may exclude small-sized dairies from high value supply chains, making both farmers and processors more sensitive to economic shocks (Mather, 2005).

Depending on the milk availability in their collection area and the demand for dairy products throughout the year, small-scale dairy processors may compete for the available milk supply. This situation, plus the absence of formal contracts between stakeholders, forces them to apply strategies to secure their milk suppliers (Siqueira et al., 2008). They can offer attractive prices to farmers when milk payment is based on quantity as is generally the case, or paying bonuses for good milk quality to fulfill formal markets requirements (Espinoza-Ortega et al., 2007; Gorton et al., 2006). The establishment of successful milk quality premium programs can attract new dairy suppliers, motivate other milk producers to

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focus their efforts on farm management practices (Botaro et al., 2013) and improve the general milk quality status at plant gate (Nightingale et al., 2008). On the market side, dairies may target a diversity of retailers, from local shops to supermarkets (Reardon and Hopkins, 2006). They have to decide accordingly on the type of products to be processed, from pasteurized milk to more sophisticated dairy products such as cheese, yogurt and ice-cream. Processing costs, inputs and output costs and milk quality may become critical aspects that influence the decision on how they can respond to market opportunities.

Small-scale dairy processors require various services to improve their technical knowledge and management capacity in order to better perform and be more competitive (Beyene, 2002; Le Gal et al., 2003). These services can include various components such as credit facilities or training sessions regarding processing techniques or the use of management tools. Nevertheless, there is also a need to help them address strategic issues such as market orientation and design of quality-based payment systems for dairy farmers (Bennett et al., 2006), specifically for small-scale firms (de Carvalho and Costa, 2007). In that respect, simulation modeling combined with scenario analysis may be key to helping managers evaluate the best strategic decisions to make (Le Gal et al., 2011), and to favor the building of a collective understanding and agreement regarding milk price selection in dairy production systems for both farmers and processors (Bouche and Attonaty, 1999).

In the last few decades, the use of different simulation tools has allowed the dairy industry worldwide to evaluate "ex-ante" potential solutions to issues such as selecting a milk price or dairy product portfolio (Table 1), and the potential impacts of manufacturing processes on their performances (Geary et al., 2010; Roupas, 2008). Simulation tools have been used for better understanding the dynamics between stakeholders and designing efficient dairy supply organizations, which increase market share, reduce costs, increase profitability and improve milk quality (Tripathi, 2011). In other industrial sectors, simulation tools have supported the design of new payment schemes (Lejars et al., 2010), better co-operation in negotiation agreements (Foroughi, 2011) and have facilitated strategic discussions between stakeholders (Hall et al., 2007; Le Gal et al., 2008). Despite all these benefits, little research has been published regarding simulation tools adapted to, and used with, small-scale dairy processors and considering milk quality-based payment systems.

This paper aims: (i) to present a decision support model based on the design of a spreadsheet called DairyPlant, in order to calculate the daily profit obtained by a dairy processing unit and the gross revenue obtained by each of its suppliers according to its product portfolio, its milk payment system and its suppliers' individual milk quantity and quality profile; and (ii) to illustrate the model application with results from two small-scale dairy processors in the Peruvian Andes (Mantaro Valley), where an increased annual milk production has been observed, but where farmers and processors still show little concern for quality norms (Fuentes et al., 2015).

2. Model description

2.1. Model development process and specifications

DairyPlant was designed based on participatory research conducted with five small-scale dairy processors in the Mantaro Valley (75°18′ longitude West; 11°55′ latitude South; 3200 m above sea level) in Peru's central Andean region. They were monitored weekly from May to July 2013 in order to examine production functions from raw milk to dairy products. Then, the support process was conducted with only two dairy processors because of their willingness to adopt innovative incentives, to carry out the support process and to discuss the feasibility of implementing changes in their product portfolios and payment systems.

This process included the following steps. Firstly, the support process, its objectives and the general idea behind the simulation tool were clearly explained to the processor in order to avoid misunderstandings. Then, an interview with the processor was conducted to better understand its dairy circumstances and management processes. Quantitative data were collected such as volume of milk collected per day, dairy products produced, price of dairy products, cost of processing dairy products, as well as qualitative data, such as means of selecting the product portfolio and payments to farmers. These data were used both to design a software structure able to cope with a variety of dairy cases, and to construct a reference scenario as close as possible to each given case.

The reference scenario was simulated in order to compare its outputs to the figures known by the processor. Calibrations were made if the processor estimated that certain results were not representative or if a lack of consistency was detected. So this scenario enabled the processor to understand the tool structure and to validate the description of his plant structure and his current operation. Once a satisfactory representation of the manufacturing process was achieved, the construction of alternative scenarios began, jointly with the processor, in order to explore various possibilities regarding the topic of interest. Outputs from these alternative scenarios were compared and discussed with each processor and the support process was evaluated with them in a final meeting. The whole process improved the model structure and the software interfaces.

DairyPlant was designed to fulfill the following specifications already implemented in similar simulations tools dedicated to

Table 1
Simulation tools reported globally for the dairy processing sector. *Source:* Geary et al., 2010, updated with additional models published between 2010 and 2015.

Type of model	Objective	References
Cost model	Calculate the cost for specific dairy activities and processes	Krell and Wietbrauk (1993), Quinlan et al. (2012).
Cheese yield model	Determine predictive formulas for yield of cheese varieties	Van Slyke and Price (1949), Barbano and Sherbon (1984), Coggins (1991)
Milk value model	Estimate the economic value of each milk component based on an analysis of a dairy products portfolio	Bangstra et al. (1988)
Multiple component pricing model	Calculate the best milk price processors can pay to producers on the basis of more than one milk component (fat and protein; protein, lactose and minerals; etc)	Emmons et al. (1990), Wallace et al. (2002), Garrick and Lopez-Villalobos (2000).
Optimization model	Find the best possible choice of processing, out of a set of alternatives, using mathematical expressions	Papadatos et al. (2002), Burke (2006), Foucquier et al. (2012)
Others	Determine seasonal and environmental effects on dairy processing	Tomasula et al. (2013), Geary et al. (2012), Marchini et al. (2014)