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University College Cork, Ireland
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Thesis to obtain the Joint International Doctoral Degree from Montpellier Supagro (France) and University College Cork (Ireland)

SIBAGHE Doctoral School (Integrated Systems in Biology, Agronomy, Geoscience, Hydroscience and Environment) and UCC Department of Food Business and Development

Defended in public on 27th November 2014
by:

EDUARDO FUENTES NAVARRO

# Exploring alternatives for milk quality improvement and more efficient dairy production in a smallholder farming context – Case study: Mantaro Valley (Peru)

Composition of the thesis jury:

Dr. Charles-Henri Moulin, Montpellier Supagro (France) – Jury President
Dr. Marijke D'Haese, Ghent University (Belgium) - Reporter
Dr. Philippe Lescoat, AgroParisTech (France) - Reporter
Dr. Carlos Gómez, Universidad Nacional Agraria La Molina (Peru) - Examiner
Dr. Stephen Onakuse, University College Cork (Ireland) - UCC representative
Dr. Pierre-Yves Le Gal, CIRAD (France) – Supervisor

Co-supervisor:

Dr. Joe Bogue, University College Cork (Ireland)

This thesis was elaborated within the framework of the European Erasmus Mundus Programme "Agricultural Transformation by Innovation (AGTRAIN)"

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**Abstract**

Consumer demand is revolutionizing the way products are being produced, distributed and marketed. In relation to the dairy sector in developing countries, aspects of milk quality are receiving more attention from both society and the government. However, milk quality management needs to be better addressed in dairy production systems to guarantee the access of stakeholders, mainly small-holders, into dairy markets. The present study is focused on an analysis of the interaction of the upstream part of the dairy supply chain (farmers and dairies) in the Mantaro Valley (Peruvian central Andes), in order to understand possible constraints both stakeholders face implementing milk quality controls and practices; and evaluate "ex-ante" how different strategies suggested to improve milk quality could affect farmers and processors' profits. The analysis is based on three complementary field studies conducted between 2012 and 2013. Our work has shown that the presence of a dual supply chain combining both formal and informal markets has a direct impact on dairy production at the technical and organizational levels, affecting small formal dairy processors' possibilities to implement contracts, including agreements on milk quality standards. The analysis of milk quality management from farms to dairy plants highlighted the poor hygiene in the study area, even when average values of milk composition were usually high. Some husbandry practices evaluated at farm level demonstrated cost effectiveness and a big impact on hygienic quality; however, regular application of these practices was limited, since small-scale farmers do not receive a bonus for producing hygienic milk. On the basis of these two results, we co-designed with formal small-scale dairy processors a simulation tool to show prospective scenarios, in which they could select their best product portfolio but also design milk payment systems to reward farmers' with high milk quality performances. This type of approach allowed dairy processors to realize the importance of including milk quality management in their collection and manufacturing processes, especially in a context of high competition for milk supply. We concluded that the improvement of milk quality in a smallholder farming context requires a more coordinated effort among stakeholders. Successful implementation of strategies will depend on the willingness of small-scale dairy processors to reward farmers producing high milk quality; but also on the support from the State to provide incentives to the stakeholders in the formal sector.

**Key words:**

Informal market, supply chain management, dairy processing, husbandry practices, modeling.

**Résumé**

Les demandes des consommateurs sont en train de révolutionner la manière dont les produits sont produits, distribués et commercialisés. En ce qui concerne le secteur laitier dans les pays en développement, les composantes de la qualité du lait reçoivent plus d'attention à la fois de la société et du gouvernement. Toutefois, la gestion de cette qualité doit-être mieux prise en compte dans les systèmes de production laitière, pour garantir l'accès des acteurs, principalement les petits exploitants, aux marchés laitiers. La présente étude se concentre sur l'analyse de l'interaction de la partie amont de la filière laitière (agriculteurs et laiteries) dans la vallée du Mantaro (Andes centrales du Pérou), afin de comprendre les contraintes possibles auxquelles ces deux acteurs sont confrontés pour la mise en œuvre des contrôles et des pratiques de qualité du lait , et d'évaluer "ex-ante" comment les différentes stratégies pour améliorer la qualité du lait pourraient affecter les revenus des agriculteurs et des transformateurs. L'analyse est basée sur trois études complémentaires menées sur le terrain entre 2012 et 2013. Notre travail a montré que la présence d'une double filière, combinant les marchés formels et informels, a un impact direct sur la production laitière aux niveaux technique et organisationnel, affectant les possibilités pour les petites laiteries formelles de mettre en place des contrats écrits impliquant des engagements sur la qualité du lait. L'analyse de la gestion de la qualité du lait, des fermes aux transformateurs laitiers, a montré sa mauvaise qualité hygiénique dans la zone d'étude, même quand les valeurs moyennes de la composition du lait sont élevées. Certaines pratiques d'élevage évaluées au niveau de l'exploitation ont démontré leur efficacité économique et leur impact sur la qualité hygiénique. Toutefois, l'application régulière de ces pratiques était limitée, puisque les petits agriculteurs ne reçoivent pas de prime pour un lait de meilleure qualité. Sur la base de ces deux résultats, nous avons co-construit avec des petits transformateurs laitiers formels un outil de simulation pour montrer des scénarios prospectifs, où ils pouvaient choisir leur meilleur produit, mais également concevoir des systèmes de paiement du lait pour récompenser les agriculteurs pour la qualité de leur lait. Ce type d'approche a permis aux transformateurs laitiers de comprendre l'importance d'inclure cette gestion de qualité dans leur processus de collecte et de fabrication, en particulier dans un contexte de forte concurrence pour l'approvisionnement en lait. Nous concluons que l'amélioration de la qualité de petits agriculteurs exige un travail plus coordonné entre les différentes parties prenantes. Une telle mise en place de stratégies dépendra de la volonté des petits transformateurs laitiers de récompenser les agriculteurs qui produisent un lait de haute qualité, mais aussi du soutien de l'Etat aux parties prenantes du secteur formel.

**Mots-clés**

Marché informel, gestion de la chaine d'approvisionnement, transformation du lait, pratiques d'élevage, modélisation.

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## Chapter 1: General Introduction

### *1.1. Study rationale*

#### *1.1.1. Small-scale dairy farmers and dairy supply chains in developing countries*

Despite the worldwide expansion of large-scale industrial dairy production, more than 80 percent of milk produced in developing countries comes from small-scale producers. Small-scale dairy farmers practice a mixture of commercial and subsistence production. They combine crops and dairy production with off-farm activities (McDermott et al., 2010), which contributes to higher food production and farm income (Babatunde and Qaimb, 2010). Dairy production plays an important role in providing food security, essential nutrients to child growth (Bennett et al., 2006), and a source of income and employment to millions of smallholder families (Martínez-García et al., 2013). In addition, it enhances the livelihoods of smallholders, promoting regular monetary earnings to farmers; providing high profit margins, low production costs, low liabilities, limited liquidity risk, and relative resilience to rising feed prices (FAO, 2010).

The rapid economic growth and the higher consumption of dairy products in developing countries have created new opportunities for improving dairy production both quantitatively and qualitatively. This situation has also provided facilities for the possible inclusion of smallholder farmers in remunerative dairy markets. However, involving small-scale farmers in supply chains requires governments' clear understanding of supply processes in order to develop mechanisms that guarantee smallholders' access to these markets (Omore and Staal, 2009).

We can delineate a dairy supply chain as a group of stakeholders linked to achieve a more effective and consumer-oriented flow of dairy products. It starts with raw milk production and ends when other processors, institutions and consumers utilize the products that were created in the value chain. Dairy supply chains comprise six core activities such as production, transportation, processing, packaging, storage and consumption (Muhammad et al., 2014). In developing countries, the weak coordination process between milk producers, traders and retailers (Seifu and Doluschitz, 2014) makes difficult the optimization of the delivery of goods, services and information from one supplier to another.

Different studies reported a large variation of organizations involved through dairy supply chains in developing countries, especially in contexts where various forms of organizations work simultaneously in the same area and influence the way milk is produced, processed or commercialized. Dairy supply chains may vary from dairy farmers delivering raw milk directly to consumers (Thorpe et al., 2000) to an industrial plant collecting milk through collecting cooperatives (Sraïri et al., 2009) or cheese processors collecting milk by themselves (Brokken and Seyoum, 1990).

Moreover, dairy sectors are composed by formal and informal markets, increasing the complexity of these supply chains. Formal markets consist of supermarkets and retail stores buying from dairies and selling to wealthy urban consumers. These markets demand a constant quality of products and a guaranteed safe product based on HACCP hygiene labels. Only companies constituted as dairies can respond to these specifications including milk pasteurization and labels on the products that indicate ingredients, track and trace data and an expiration date. Payment is made with receipts and payment of taxes. Informal markets mean that operators do not follow official regulations to produce standard dairy products; work in an environment without any tax regulation, strict or permanent quality controls and labeling of dairy products; and target consumers with a lower purchasing power. Formal and informal markets may differ according to criteria such as existence and application of official quality standards, contracts between stakeholders along the supply chain, or public tax charges on transactions.

The national balances between formal and informal markets vary greatly from one country to another, from mostly ‘informal’ countries in the developing world to Western countries where the informal sector is almost non-existent (Table 1). In that respect, Peru represents an intermediate situation, where the two markets occupy a similar position in terms of milk quantities processed and in some cases, share the same area of milk collection or commercialization of dairy products. Therefore, identifying advantages and disadvantages small-scale farmers and dairy processors face supplying milk these formal and informal markets can help those improving their supply management in order to increase their benefits.

**Table 1:** Respective share of informal and formal trade in various national dairy sectors

| Group | Countries | % of milk processed by formal sector | References |
|---|---|---|---|
| **Informal dominant** | Tanzania, Ethiopia, Uganda, Rwanda, Sudan, Kenya, Egypt, Cameroon, Senegal, Turkey, Nicaragua, Lebanon, Bangladesh, India. | <30 | Padilla et al., 2004; Staal, 2006; Rao and Odermatt, 2006 |
| **Medium** | Peru, Costa Rica. | 40-60 | Knips, 2006; Staal, 2006; Rao and Odermatt, 2006 |
| **Formal dominant** | Argentina, Brasil, Mexico, Morocco, Algeria, Tunisia, Albania, Sri Lanka, Thailand. | 60< <100 | Padilla et al., 2004; Knips, 2006; Staal, 2006; Rao and Odermatt, 2006 |
| **Only formal** | EU, USA. | 100 | According to EU and USDA legislation |

*1.1.2. Dairy supply chain management as response of market demands*

Milk is a bulky and heavy commodity which requires high-cost storage and transportation and it spoils quickly without cooling (Knips, 2005). Each segment of the dairy supply chain is composed of stakeholders that make decisions based on their own interests (Wang and Zhao; 2007). At the farmer level, supply chain management is based on providing a rather constant flow of milk to dairies and receiving a financial flow in the opposite direction. In the downstream part of the supply chain, retailers and manufacturers are more concerned in functional points such as production specificities and required technological parameters (Hanf and Pieniadz, 2007), whereas price, freshness, taste, and animal welfare are highly relevant to consumers.

Today's dairy supply chain management is orientated toward controlling milk quality and supply fluctuations. Milk quality is the primary factor determining the quality of dairy products, since good-quality milk products can be produced only from good-quality raw milk. Good-quality raw milk has to be free of debris and sediment; free of off-flavours and abnormal colour and odour; low in bacterial count; free of chemicals (e.g., antibiotics, detergents); and with an adequate level of chemical composition and acidity (FAO, 2009). The emergence of supermarkets in developing countries have led to structural changes in the way dairy products are inspected, processed, packaged and supplied

to consumers. Consumer demand for high-quality milk has started to increase in urban areas and it has placed increasing pressure on milk producers to achieve higher product standards (Dong et al., 2012). This change has had an impact on producers and processors, particularly in determining who can and who cannot participate in the mainstream of these supply chains (Steinfeld et al., 2006). In fact, lack of compliance with food safety and quality standards may exclude smallholders from the quality-driven supply chains (Birthal and Joshi, 2007).

*1.1.3. Main issues faced by management of milk quality in dairy supply chains based on small-scale farmers*

Management of milk quality along the supply chain remains as an important component for assessing the performance of dairy supply chains, particularly in developing countries where most stakeholders show limited labor and capital capacities (Sraïri et al., 2009). Many studies have highlighted the importance of farm and collecting management practices on milk quality (Elmoslemany et al., 2010). For instance, a higher number of crossbred cows in a herd and using an adequate amount of quality roughage and concentrates in the diet would increase milk production and milk composition (Millogo et al., 2008). Clean cows provide the lowest somatic cell linear scores compared to dirty cows (Sant'Anna and Da Costa, 2011). Milking practices, such as fore-stripping after udder cleaning, pre-milking udder and teat cleaning by wiping, decrease the total microorganism counts (Kamieniecki et al., 2004). Furthermore, cooling milk after milking reduces the risk for the growth of milk bacteria (Sraïri et al., 2005). An increased level of hygiene and frequent cleaning of the milking buildings leads to a lower somatic cell count (Kelly et al., 2009). Increasing the number of milk collections per day reduces the total bacterial count in raw milk (Van Shaik et al; 2005), while controlling milk temperature and heating raw milk on arrival at dairy processing units prevents bacterial growth (Koussou and Grimaud, 2007; Millogo et al., 2008).

In most dairy industrialized countries milk quality is defined by the level of somatic cells (SCC) in the pre-pasteurized bulk tank. It is a key component of international regulation for milk quality, udder health and the prevalence of clinical and subclinical mastitis in dairy herds. High levels of SCC are associated with poor milk quality because they have a negative impact on (i) farm profitability:

economic losses related to treatment, culling and reductions in milk yield; (ii) milk processing: reduced curd firmness, decreased milk yield, increased fat and casein loss in whey and a reduction of its shelf life; and (iii) human health: indirect risks as a result of poor farm hygiene, antibiotic residues and the presence of pathogenic organisms and toxins in milk. The situation is still different in developing countries where most of the time there are not quality control structures and there are critical issues which need to be addressed first, like the dysfunction of regulatory and quality control systems. Problems of public health related to the consumption of raw milk and traditional dairy products prepared from raw milk are common in these countries (Makita et al., 2012). Inadequate storage facilities and transportation systems, high hygienic contamination through the dairy supply chain and poor handling procedures in the market compound the difficulties of improving the safety dairy products (Delgado and Maurtua, 2003; Gran et al., 2002). These problems are aggravated by local climatic conditions and the lack of a cold chain (Faye and Loiseau, 2000).

Besides poor hygienic quality control, adulteration of milk composition is also an important issue that these dairy sectors face today. The addition of extraneous substances such as water to increase volume of milk, agents to counter the dilution and extend the solids content of the milk, chemicals to increase the storage period of milk, detergents to enhance the cosmetic nature of milk, or minerals for whitening of milk and giving it a genuine look cause major economic losses for the processing industry (Barham et al., 2014). Various physical techniques are used to detect these types of milk adulteration (Kasemsumran et al., 2007).

Farmers' decision to apply or not apply quality management practices will depend on the existent pressure to commercialize their milk at a higher price and the presence of less or more demanding dairy processors buying raw milk. But it becomes infeasible for many dairy processors to test every milk sample collected due to high testing costs and the large number of small-scale dairy producers. However, with quality problems receiving more attention from both society and the government and the increasing pressure to achieve higher product standards, dairy companies are pushed to improve their current milk quality status. In this respect, implementation of milk quality controls and incentive payment systems based on quality are widely used in industrialized countries. However, in developing countries these controls and quality-based pricing need to be better adapted to the reality of dairy

stakeholders and have to be aligned to concrete strategies for improving milk quality; especially in a context with a predominant presence of smallholder farmers.

*1.1.4. Importance of milk quality controls and incentive systems for achieving high milk quality*

Despite the fact that many people are persuaded that “milk is milk” and that is the end of the matter, there is evidence of a significant variation in milk composition from cow to cow (Smit, 2003). These variations are explained by genetics, stage of lactation, daily variation, parity, type of diet, age, udder health and season (Kilic and Kilic, 1994; Haenlein, 2003). Part of this variation is reduced by a combination of milk from many animals at the farm level. However, if collections from various farms are accumulated in the same milk tanker and in the silo at the factory (Smit, 2003), it is technically impossible to identify which farms are producing milk with higher or lower quality. Hence, a milk quality test per farm helps dairy producers to correct methods and identify inefficiencies in their milk production (Tessema and Tibbo, 2009). Additionally, it also helps quality control personnel (in dairy plants and regulatory agencies) to monitor milk quality in order to reject milk which falls below the minimum quality requirements and avoid possible adulterations. The analytical method used to control milk quality depends on the objective of the analysis, the need for a fast result, the instrumentation available, the specialized personnel available and the cost (Tamime, 2009). These methods are divided into the following groups: organoleptic characteristics, compositional characteristics, physical and chemical characteristics, hygienic characteristics, adulteration and presence of drug residues (FAO, 2009). Reference methods have been developed and published by the major standard associations in order to have them as standard tests. Some of these methods are listed in Table 2.

Rewards or incentives are used to improve dairy farms’ performance and are typically paid by processors when a predetermined level of milk quality is attained (Stup et al., 2006). Incentives include not only payment systems but also services related to the raw material supply i.e. contracts to provide feed for calves and heifers, farmer training programs, availability of credit or preferential payment, access to farm management and profitability advice (Moran, 2005). These incentives could be attractive for farmers especially when the proposed price is quite homogeneous from one processor to another.

**Table 2:** Testing methods used for various milk quality components

| Tested milk quality component | Testing method |
|---|---|
| Fat | Gerber |
| Protein | Formaldehyde |
| Water addition | Lactometer and freezing point |
| Temperature | Thermometer |
| pH | pH meter |
| Clot | Boiling |
| Acidity | Alcohol and titratable acidity |
| Milk hygienic status | Resazurin, methylene blue, total bacterial count, somatic cell count |

Milk payment systems differ from country to country, region to region, company to company and so on (IDF, 2006). For instance UK and Czech Republic have a current payment system based on volume but with a differential for variation in milk composition. Countries like Austria and Germany have a payment system based on a per-kilogram basis (Summer, 2007). Differential payment systems and incentives may vary according to the production type and the characteristics of raw milk in the region. Depending on market demand and the supply situation, dairies may be interested in receiving homogeneous deliveries of raw milk or raw milk with different fat percentages. Indeed, higher fat percentage is demanded if dairies sell a lot of cream, butter and other high fat products, but are low if there is a surplus of fat that cannot be utilized (FOSS, 2005). Deduction in milk price and rejection levels to discourage milk adulteration and improve farmers' milk quality management practices are also commonly applied worldwide (Table 3).

**Table 3:** Incentives or penalties applied worldwide to improve raw milk quality

| Incentive or penalty | Criteria |
|---|---|
| **Increased price factor** | High milk fat and protein, low bacteria content, low somatic cell count, fresh and refrigerated at 5°C |
| **Reduced price factor** | Low milk fat and protein, moderate bacteria content, moderate somatic cell count, high milk temperature |
| **Rejection factor** | Added water, too high bacteria content, too high somatic cell count, inhibitory substance/antibiotics and harmful contaminants. |

**Source:** FAO (2009)

Producers' price is also subject to seasonal adjustments, especially when contrasted seasons exist leading to high and low milk production. For example, seasonal milk price differential is commonly applied in UK and varies from -14.5% of the base price in May to +30.3% in August (Varnam and Sutherland, 2001).

#### *1.1.5. Conclusions*

The upstream part of dairy supply chains (farmers and dairies) in developing countries faces the presence of numerous stakeholders as well as formal and informal markets pursuing their own interests and benefits. Changes in consumer demand are modifying the way dairy products are inspected, processed, packaged and supplied to consumers; and high-quality milk is increasingly demanded from milk producers. However, difficulties related to milk adulteration and poor hygienic management affect the supply of high milk quality. On-farm milk quality controls can help to correct these problems. Nevertheless, high testing costs and the large number of small-scale dairy producers limit dairy processors' willingness to test every milk sample collected. Attractive incentive programs adapted to local needs may provide positive results on the improvement of milk quality management, while ensuring the continuous supply of high quality raw materials. Nevertheless, other strategies to improve milk quality also need to be explored.

The next sub-section presents our case study which attempts to find alternatives for improving milk quality and the efficiency of dairy production in a context with predominant presence of small-scale farmers and a production system with a simultaneous participation of formal and informal markets.

### ***1.2. Context of the study***

#### *1.2.1. Characteristics of the Peruvian dairy sector*

Although Peru has one of the lowest levels of dairy consumption on the continent (Aubron et al., 2009), throughout the last decades there has been a consistent trend to increase dairy production. Indeed, milk production in Peru has experienced a constant annual growth of around 4%, i.e. from

830,146 ton in 1994 to 1,705,719 ton in 2008 (MINAG, 2009). Three main drivers have contributed to this growth: (i) the growing urban demand for dairy products; (ii) the national protection of the dairy sector from imports through 2008; and (iii) the food aid regime, based on the "Programa Nacional de Asistencia Alimentaria" (PRONAA) currently called Qali Warma, which provides milk to school children (Knips, 2006). Despite this progress, the involvement of the Peruvian government regarding policies for the dairy sector has not been constant over the last decades. In the 1980s, the government controlled wholesale and retail prices and managed import quotas in order to incentivize the development of the industrial sector, replacing the imports with national milk and keeping consumer prices for dairy products low (Bernet, 1998). In the beginning of the 1990s, the Peruvian Government decided to protect its national market from cheap imports by implementing tariffs and a price band system for import of dairy products. Similar decisions have been made by other countries such as Morocco and Tunisia, which has led to large investments in local dairy production and allowed small-scale farmers to be involved in this sector (Sraïri et al., 2013). Nevertheless, these tariffs and price band system were removed in the medium term to favor the trade with the Andean Community of Nations and United States; and were completely abolished in 2008.

According to FAO (2006), the dairy industry in Peru has three main production systems, each one with its own characteristics and different challenges: (i) Large-scale dairying, where milk production is based on stall-feeding dairying or intensive strip grazing systems, generally practiced in the coastal lowlands of Arequipa, La Libertad and Lima; (ii) tropical dual-purpose dairy production in the semi humid lowlands of the Amazonian region, based on a low input, low management and a low risk pasture system; and (iii) small-scale dairy production in the central highlands, linked to horticultural and other irrigated crops in the valley bottoms and natural grazing for extensive cross-breed dairy breeding on the upper slopes. From these production systems, dairy production in the central highlands is part of our particular interest because of the amount of rural small-holders involved. Eighty-eight percent of the total population of cattle in the country is located in the Andes. Dairy cattle also provide draught power, manure and sometimes function as a source of cash reserves (Drucker et al., 2001; Rojas and Gómez, 2005). The development of transportation channels in the 90s have contributed to expanding milk collection routes and fostering faster transportation of highly perishable items such as raw milk, cheese and yogurt from the Andes to the urban centers. Dairy production has

greatly increased in these areas in the past fifteen years and farmers currently receive a reasonable milk price and produce high milk yields per animal; however, dairy farming systems still need to be significantly improved through adequate animal and pasture management, forage conservation and in general, better quality management of the enterprise.

Nowadays, the Peruvian government promotes the dairy sector in the central highlands mainly through developing social feeding programs like Qali Warma, which provides quality food (including milk and dairy products) to school children. Nevertheless, it is not currently involved in providing support or any direct subsidy either to the local dairy production (credit or inputs) or to the dairy industry, even when contracts between credit institutions and milk processors have proven to be very cost-effective in the Andes (Bernet et al., 2002). Farmers in the central highlands usually demand technical and economic support from the government, but they are not so optimistic about the real involvement of the state in the region (Trivelli et al., 2006). Only a few public organizations are present in these areas like Sierra Exportadora and Regional Governments, but these play a limited role in promoting innovation and are not sufficient to boost the dairy sector (Ortiz et al., 2013). Consequently, farmers and processors are exclusively dependent on their own profits to invest in their business. This situation could hinder the possible expansion of the sector and increase smallholder farmers' economic vulnerability. Despite this lack of economic support available to farmers and processors, active State intervention in the Andean dairy sector is suggested (Bernet et al., 2001) in order to alleviate poverty in the area (Kristjanson et al., 2007).

Since the demand for milk is still increasing and some central areas are located not too far from coastal cities, increasing milk production might be an interesting development strategy for small-scale farmers in the central highlands (Bernet 2000). The Mantaro Valley is one of these highland areas, because of its potential for development of the dairy sector: It has relatively good access to markets, farmers cultivate pastures all year long, people depend on milk production for their livelihood income, there is a large variety of stakeholders in the area, and it is relatively close to Lima, the Peruvian capital located at 270 km from this valley.

*1.2.2. Dairy production at Mantaro Valley*

The Mantaro Valley is located in the department of Junín in the Central Andes (75º18´ longitude West; 11º55´ latitude South; 3,200 meters above sea level) (Figure 1). The local annual rainfall varies between 600 and 765 mm per year, but most of the dairy production benefits from irrigated forages such as rye-grass, clover and oats, cultivated on surface irrigation schemes.

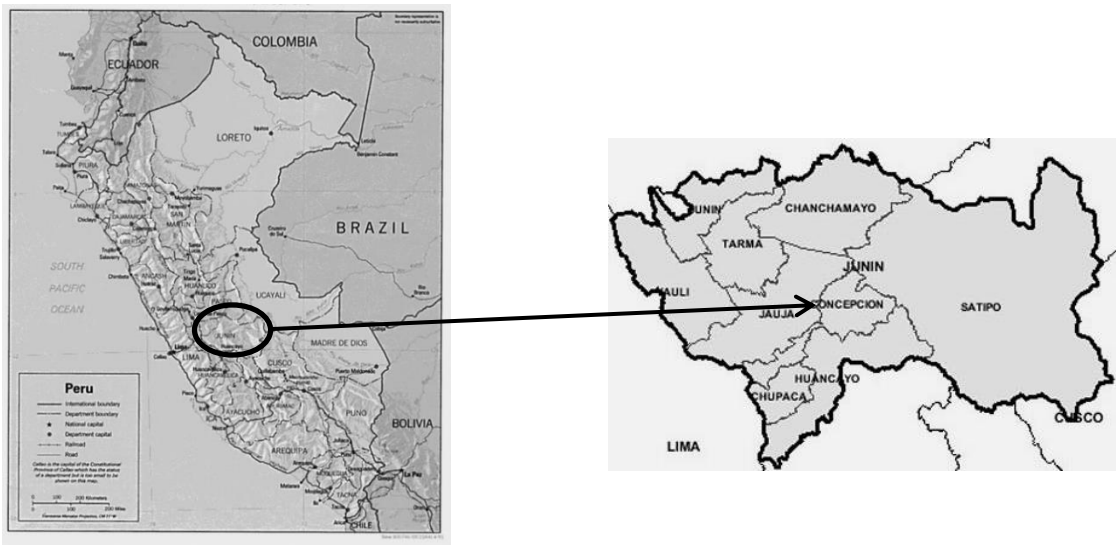



**Figure 1:** Localization of Mantaro Valley

Dairy production has been important in the area since the 1960s thanks to the development of industrial companies funded both publicly and privately, and to the commercial links with the wholesale market in Lima. The national land reform program conducted in the early seventies favored the dismantling of large haciendas and the emergence of small-scale farms and co-operatives. Nevertheless, collective co-operatives set up in the area failed to increase agricultural productivity, in comparison with other areas of the country because of farmer's preference for individualization of land use and ownership (Scurrah and Caravedo, 1991; Trivelli et al., 2006). The terrorism movement active in the area during the 1980s also negatively affected the local economy, discouraging producers from investing in farms including those in the dairy sector (Fernandez-Baca and Bajorquez, 1994).

From being the second most important national production area in the 1970s, the Mantaro Valley nowadays provides only 2% of Peruvian dairy production. However, milk production has been increasing since 1994, reflecting much of the dynamic growth found at the national level (Figure 2).

Indeed, the establishment of a collection centre belonging to a multinational dairy company in 2005 has provided to local dairy farmers access to technical support and credit (Aubron, 2007), and the possibility to increase their milk production by offering a secure outlet for their produce.

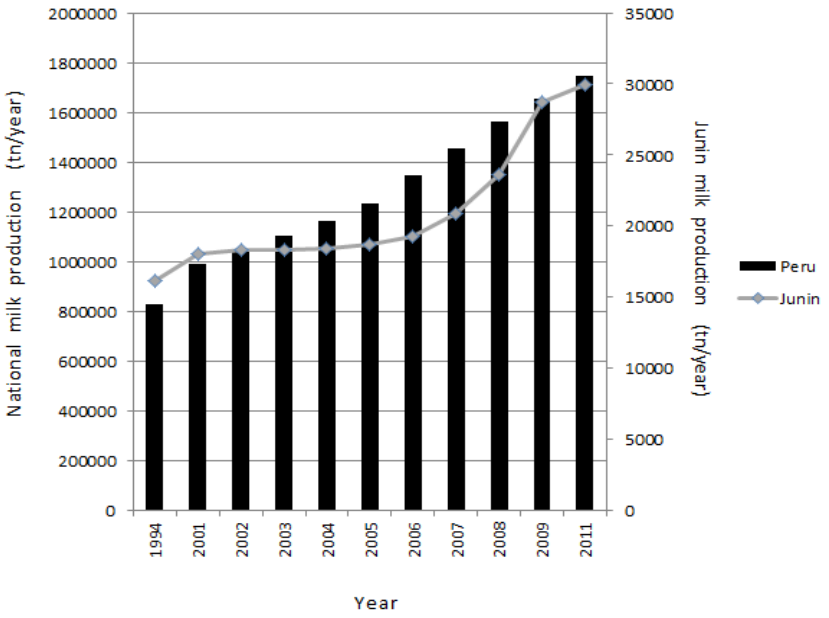



**Figure 2:** Evolution of dairy production at National level and in the department of Junín (Mantaro Valley) from 1994 to 2011. The figure shows the similar trend in terms of increased volumes over time.
(Source: MINAG, 2014 and INEI, 2010)

This dynamic combined with the turbulent history of dairy production in the region has led to a large variety of dairy farmers, collecting and processing actors from both formal and informal markets co-existing in the same area:

*1.2.3. Dairy farmers*

Smallholder farmers account for around 60% of the dairy farms in the area. They on average cultivate less than 2 ha and own no more than 6 dairy cattle, including two lactating cows in production. The average production per cow and per farm is 8.6 l/day and 18 l/day respectively. Despite their vast number, these small-scale farmers account only for 30% of the total milk production in the area. Indeed, they have poor access to some services like credit (only 19% have access), concentrate supply (62%) and training (29%). Fifty-one per cent of them have limited access to land leading to high

stocking density. They cultivate various types of forage associations (oat forage-vetch forage, rye grass-red clover, or alfalfa) and crops (potatoes, corn, carrots, beans, peas and artichokes) in order to increase their returns and simultaneously reduce risks. However, this crop diversity on small cultivated areas leads to difficulties in providing a constant feeding diet to their cows in a green forage-based system. Approximately 68% of farmers have to buy fodder during most of the year to complement their own forage production. The diversity of dairy farmers leads to a large variability of daily milk quantities supplied per farm, ranging from 5 up to 300 l/day.

*1.2.4. Milk collectors*

Milk collectors collect up to 35% of total milk per day, and up to 50% if collectors who process part of the milk are included. Collectors' milk collection varies between 400 to 5000 liters per day. These large quantities can be obtained by prospecting production areas far from dairy industries' own supplies (approximately 30 km). Milk is bought from farmers who cannot find enough buyers due to their remote location. To recover part of transportation costs farmers are paid 10-20% less per liter of milk than the average price in the area. This system provides a good source of income to collectors based on a small profit per liter assuming a permanent collection volume above 1000 liters per day.

*1.2.5. Dairy Processors*

Three main types of processor can be identified in the area: i.e. collector centers from two multinational dairy industries, several local medium-scale dairies and artisanal cheese-makers. They process respectively 44%, 27% and 29% of the total milk commercialized in the Valley. Two multinational dairy companies have installed a collection center in the study area. They receive milk from farmers or collectors at the center gate, storing it in cooling tanks for a couple of days until they have sufficient milk to be sent to Lima for processing. They accept as much milk as they can obtain. About 15 small and medium scale dairies collect from 50 up to 3500 liters of milk per day and belong to formal companies. They produce mainly fresh cheeses and yogurt. However, around half of them produce a wide diversity of dairy products such as pasteurized milk, diversified cheeses, butter, manjarblanco and ice cream. Only about 2 or 3 of these companies have been integrated in Qaly

Warma. When the program is inactive during school holidays (from January to March), its suppliers have to find other market opportunities. About 50 artisanal cheese makers process from 55 up to 5000 liters of milk per day. Despite these big volumes, all of them are informal. They buy milk and produce their dairy products, mainly fresh cheese, without pasteurizing the milk before processing it. Artisanal cheese makers use cheese molds made of reed. These molds are difficult to clean but give characteristic marks to fresh cheeses that are easily recognized by consumers in Lima's markets.

*1.2.6 Conclusions*

Most of the farmers and processors involved in dairy production in Mantaro Valley already have good opportunities to improve the quantity of their production, since the demand for dairy products is high, especially in urban areas. These improvements would help farmers, especially smallholders, to resist economic shocks. Nevertheless quantity cannot be the only parameter taken into account in an agro-food supply chain based on a perishable and rather chemically complex raw material such as milk. Improving milk quality represents an important issue that also needs to be tackled, considering the fact that (i) part of the raw milk produced in the area is oriented to urban retailers demanding safe products; (ii) local people involved in dairy production depend on provide good raw milk to ensure a constant income; and (iii) milk quality supplied to processing units affects the quantity of dairy products obtained, processors' profitability and thereby their viability in the future.

Currently, there is poor milk quality management in the area and little concern in the way smallholders supply raw milk. There is a lack of strict quality controls or payment systems including a quality component except for one collection center from a multinational company which measures acidity, density, and addition of water (cryoscopy test) of milk samples every day for every supplier (farmers and collectors) and includes bonuses and / or penalties according to the result of three quality analyzes of milk total solids, hygienic status and use of a cold chain every 15 days. In this context, alternatives for improving milk quality adapted to the characteristics of dairy production in Mantaro Valley are necessary to avoid possible future exclusions of the stakeholders from more demanding dairy supply chains.

## *1.3. Problem statement*

### *1.3.1. Research questions*

The simultaneous presence of formal and informal markets in the Peruvian dairy sector has facilitated the inclusion of small-scale farmers in remunerative supply chains and has favored an increase in the demand of raw milk in rural areas. Despite informal and formal markets differing in terms of application of official quality standards, especially sanitary standards, contracts between stakeholders along the supply chain, or public tax charges on transactions, both markets participate in terms of milk quantities processed. This particular situation of the Peruvian dairy sector compared to other countries where the informal sector is predominant or is almost non-existent is also reflected in Mantaro Valley. Nevertheless due to its originality, little information is available about its complexity and the way small-scale farmer-processor relationships affect the performance of both formal and informal processors when a diversity of markets co-exists. Moreover, improving milk quality can provide higher incomes to small-scale farmers, avoid milk adulteration and poor hygienic management of the milk collected, and give better raw material to dairy processors. There is a need to clearly understand how small-scale farmers and dairy processors may include better management of milk quality on their production systems. Thus, our study addressed the present research questions:

***What are the constraints small-scale farmers and dairy processors face for improving milk quality and the efficiency of a dairy sector, based on a production system with co-existence of formal and informal value chains?***

In order to meet this research question, we should answer some sub-questions. The first sub-questions attempt to understand the structure of the dairy supply chain and the role of milk quality in the production system. Consequently, it is essential to determine *how the dairy supply chain is currently constituted and managed, what are the interactions between small-scale farmers and dairy processors at Mantaro Valley?*, and *how do the relationships between small farmers and the formal and informal dairy companies influence stakeholders' decisions to include milk quality controls?.*

Furthermore, performing an analysis of milk quality management can provide useful insights to determine if stakeholders need to improve their production and collecting practices. Hence, it is important to know *what is the current status of milk quality in the area* and *how current stakeholders' practices regarding milk quality management affect its composition and hygienic quality?*

Lastly, supporting small-scale dairy processors interested in improving milk quality could enhance a general improvement of the whole dairy supply chain by developing high value markets but also by rewarding small-scale dairy farmers according to their milk quality. Therefore, it is necessary to recognize *what sort of support could help both farmers and processors in improving milk quality management and more generally efficiency of the dairy sector and what is the role of simulation tools in this support process?*

### *1.3.2. Research objectives*

This PhD dissertation intends to develop an in-depth analysis of the constraints small-scale farmers and dairy processors face in Mantaro Valley, in order to identify potential alternatives for improving milk quality and the efficiency of the dairy sector. The first specific objective of the study is to analyze the characteristics of milk production, milk collection and milk manufacturing in the study area; and identify interactions among stakeholders in a context of a simultaneous presence of formal and informal markets. Clear understanding of these relationships will provide key information about the organization of the dairy supply chain. The second aim is to establish the average values of milk chemical and milk hygienic quality at farm level and at plant gate and determine husbandry/manufactory practices that stakeholders follow during their milk production and collection process. This will generate a deeper knowledge of the factors which prevent stakeholders from achieving high milk quality standards. The third objective is to design and test a simulation tool as an alternative way to support small-scale dairies in improving their economic profitability. This will empower dairy processors to select relevant market orientations and design milk quality payment systems.

The district of Apata, located in the province of Jauja, and the districts of Matahuasi, and Concepcion located within the provincial parameters of Concepción, were the focal locations of this research because they concentrate the largest number of dairy farmers and processors in the area and because of their increased level of milk production in the last decades (Figure 3).

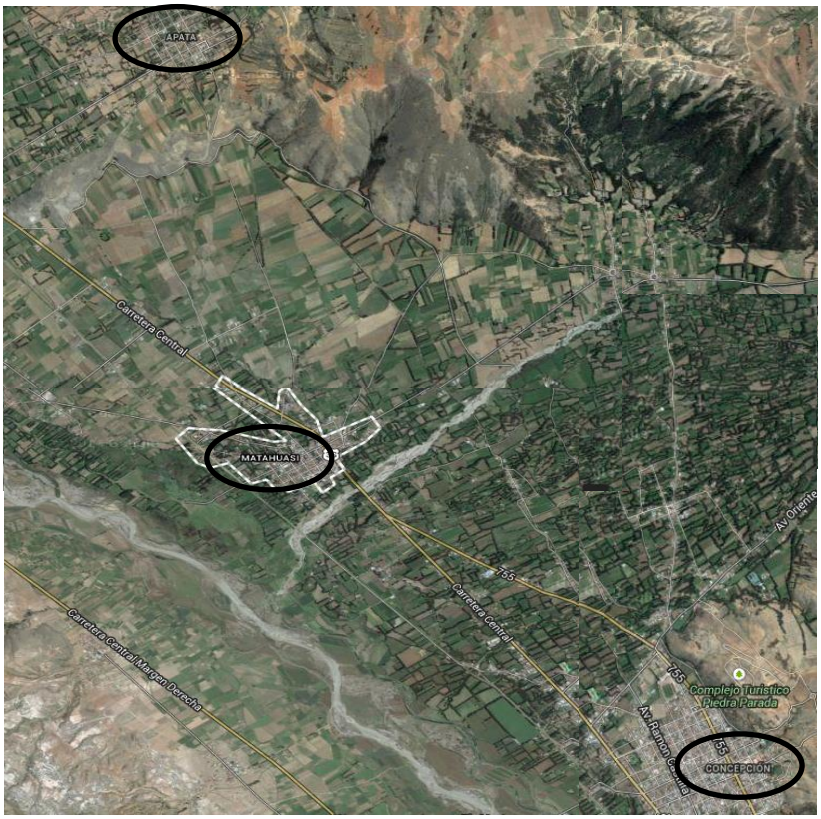



**Figure 3.** Location of the three districts included in the present study
Source: Google 2014

### *1.4. Dissertation outline*

This dissertation document is presented in the form of a publication-based thesis. It includes two volumes (Figure 4): The first volume provides a synthesis of the results obtained during the thesis and is structured in two parts. The first part concerns the results obtained during the present study. Specific materials and methods sections were included in each result chapter, because of the diversity of methods used. It comprises three chapters: Chapter 2 focused on the interactions between stakeholders and the analysis of a dual market. Chapter 3 explains the effect of husbandry/manufacturing practices on milk quality and the effects of introducing milk quality controls based on the use of an ultrasound milk analyzer machine; and Chapter 4 is a comprehensive study of

the design and usage of a simulation tool to support small-scale dairy plants in selecting market orientations and milk payment systems. The second part of the manuscript concerns analytical aspects and is structured in two chapters: Chapter 5 deals with the general discussion; and finally Chapter 6 provides a summary of major findings, conclusion and some recommendations.

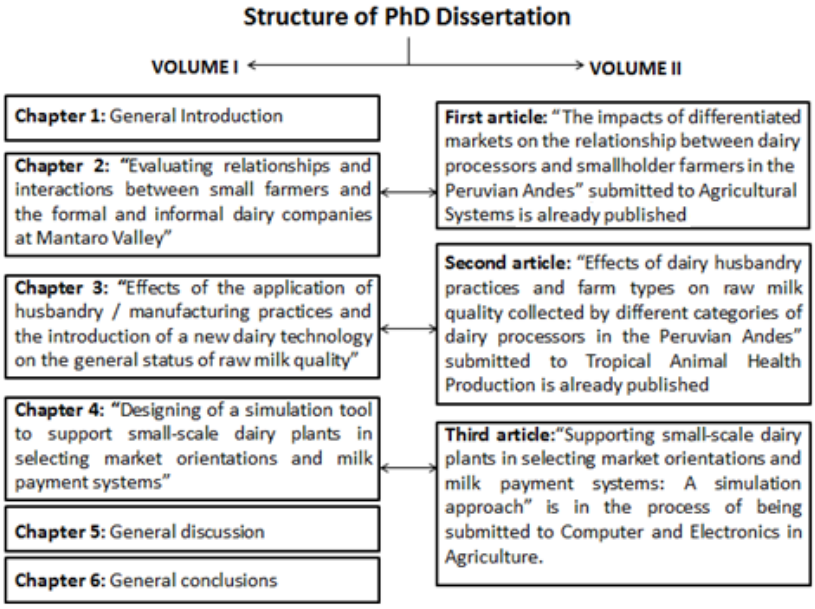



**Figure 4:** Diagram showing the structure of the PhD dissertation document presented in the form of a Publication-based thesis

The second volume consists of three scientific articles elaborated from the results of the present study. They targeted different peer-reviewed academic journals: The first one titled "The impacts of differentiated markets on the relationship between dairy processors and smallholder farmers in the Peruvian Andes" submitted to *Agricultural Systems* in September 2013 is now definitively published in volume 132, page 145-156, http://link.springer.com/article/10.1007%2Fs11250-014-0658-6#. The second one titled: "Effects of dairy husbandry practices and farm types on raw milk quality collected by different categories of dairy processors in the Peruvian Andes" submitted to *Tropical Animal Health Production* in May 2014 is published in volume 46, page 1419-1426, http://www.sciencedirect.com/science/article/pii/S0308521X14001358. The third one titled: "Supporting small-scale dairy plants in selecting market orientations and milk payment systems: A simulation approach" is in the process of being submitted to *Computer and Electronics in Agriculture*, but a complete draft is already available in this document.

***Chapter 2:*** *Evaluating relationships and interactions between small farmers and the formal and informal dairy companies at Mantaro Valley*

In the present chapter, we analyze the role of the different stakeholders and their relationships under a context of scarcity of resources, a dual market and high milk demand. Results highlight the fact that the co-existence of formal and informal markets reduces the implementation of formal contracts and favors other types of strategies to ensure a constant supply of raw milk. Milk flows between actors based on a mix of competition and complementarity process. This organization allows smallholder farmers to be included in the dairy sector without making big investments. But this co-existence provides fragility to the whole sector. The formal sector faces difficulties to achieve high milk quality standards and the informal sector has high profits per liter of milk but remains sensitive to State controls. More detail information is available in volume 2 of the present document.

**2.1 Materials and methods**

Data collection was performed between March and July 2012. A preliminary survey assessing the diversity of stakeholders' businesses and identifying the variables of milk production was conducted in March 2012. Informative questions were posed to three public organizations (Sierra Exportadora, Gobierno Regional de Junín and Pronamach) and 25 dairy processors in order to collect general data related to (i) the average amount of milk produced or collected per day, (ii) the average payment per liter of milk (iii) general perception about milk quality, and (iv) relationships among stakeholders within the supply chain in the area. Then in-depth interviews were conducted over the course of four months from April to July 2012 with three dairy processors (one large, one medium and one small); one milk collection center belonging to a multinational company; one independent milk collector; one farmer association; and at least 5 small-scale dairy farmers per processor from 3 districts of the Mantaro Valley (Concepción, Matahuasi and Apata) in order to collect data regarding interactions between actors along the supply chain, milk quality, milk prices, product quality and current state participation (Annex 1 and Annex 2). Data from two studies conducted in the Mantaro Valley between 2009 and 2011 were used to complement our analysis. The first study, conducted over four months in 2009, aimed to investigate the degree of involvement of small-scale dairy farms in local dairy supply chains.

It was based on surveys combining the collection of quantitative data and stakeholders' interviews (40 dairy farms, 12 dairy processors, and support institutions). Data related to the characterization of dairy supply chains were extracted from this analysis. The second study, carried out in 2011, intended to get an overview of the Mantaro dairy sector and determine how the commercialization system involving small-scale producers operates. For this purpose, 146 farmers and 26 dairy processors (including milk collectors) were interviewed using structured questionnaires. This study provides key information about differences in markets in which dairy processors are involved.

Descriptive statistical analyses were performed in SPSS for Windows (version 14.02, © 1989 – 2005) to perform the data analysis. Farms were aggregated qualitatively in homogeneous clusters to classify small, medium and large-scale dairy producers. Using the same process, different types of processors and their channels of commercialization were distinguished. Results of the three studies allowed the completion of cluster descriptions by including interaction characteristics between farmers and processors. A budget simulation tool was developed with Excel 2010 (Microsoft) in order to compare profits per liter of milk between producer and processor clusters. Calculations were performed by taking into account (i) the kind of market which affects the General Sale Tax (GST) recovery (yes for formal; no for informal), (ii) two specialized farm types (small and large farm) targeting both formal or informal markets, (iii) two types of processors (formal and informal, each collecting 700 l/day), (iv) average production costs based on stakeholders' practices, labor costs, the kind of equipment they use, (v) milk prices and (vi) GST rate. Calculations were made for one day of activity in two seasons: rainy (December-April) and dry (May-November). The exercise considered average production costs of dairy farmers for each type of farm, based on the 2009 farm survey. Dairy processors costs were calculated from the average costs of different formal and informal diary processors interviewed in 2012. Milk production at farm level was reduced by 20% during the dry season to simulate the effect of decreases in forage. Costs and products were reduced to one liter of milk and per day, according to the farmers' daily production of milk, or the processor's daily production of cheese by using a cheese yield coefficient (based on an average of observations made in 3 dairy plants). These indicators were chosen to allow comparison of economic efficiency between the different types of farmers/processors in the area irrespective of their sizes.

## 2.2. Synthesis of results

### *2.2.1. Large diversity of dairy supply chains*

Milk produced at Mantaro Valley is mainly sold to different types of dairy processors rather than used for self-consumption. Thirteen channels of distribution were identified at Mantaro Valley based on the kind of processor, the kind of product marketed and the kind of market involved (Table 4).

**Table 4:** Description of the thirteen supply channels identified at Mantaro Valley

| Type of processor | Product commercialized | Type of Channel | Market | % of total milk produced in the Valley |
|---|---|---|---|---|
| National dairy industries | Evaporated and UHT milk | 1 | Retailers and supermarkets in Lima | 7.3 |
| | | 2 | Local retailers and supermarkets (Huancayo) | 19.9 |
| Formal small and medium scale industries | Pasteurized fresh cheese | 3 | Retailers in Lima | 10.0 |
| | | 4 | Supermarkets in Lima | 8.4 |
| | | 5 | Local retailers (Huancayo) | 0.5 |
| | | 6 | Local supermarkets (Huancayo) | 1.6 |
| Artisanal cheese makers and informal processors | Raw fresh cheese | 7 | Retailers in Lima | 27.6 |
| | | 8 | Local retailers (Huancayo) | 4.1 |
| | | 9 | Local fairs | 1.1 |
| | Fresh milk | 10 | Local retailers (Huancayo) | 2.8 |
| Both (formal and informal processors) | Other dairy products (yogurt, butter, etc.) | 11 | Local retailers (Huancayo) | 8.3 |
| Self-consumption | Fresh milk | 12 | Local community | 3.2 |
| Self-processing | Raw fresh cheese | 13 | Local community | 5.2 |

Dairy production in the study area is oriented towards three main marketed products: fresh cheese, evaporated and UHT milk and fresh milk. Fresh cheese accounts for 53% of raw milk from the valley with or without pasteurization, while evaporated and UHT milk accounts for 27% and direct consumption of raw milk for 3%. The remaining quantities are used for other dairy products such as majarblanco (a product based on the reduction of milk and sugar), yogurt or butter (chain 11). Farmers may consume their own production (chain 12) or sell raw milk directly to local consumers (chain 13). These supply channels are composed at the processing level by a large variety of dairy processors: multinational dairy industries, several local medium-scale dairies and artisanal cheese-makers, highlighting the active participation of both formal (from 1 to 6 in Table 1) and informal markets (from 7 to 10 in Table 4) in the dairy sector (Figure 5). Formal and informal channels follow their own structure. However, it was observed that they are interdependent, since they have to deal with the same diversity of farmers who supply raw milk. This interdependence is amplified by the presence of intermediaries specialized in milk collection due to the absence of associations with milk collecting points in the area.

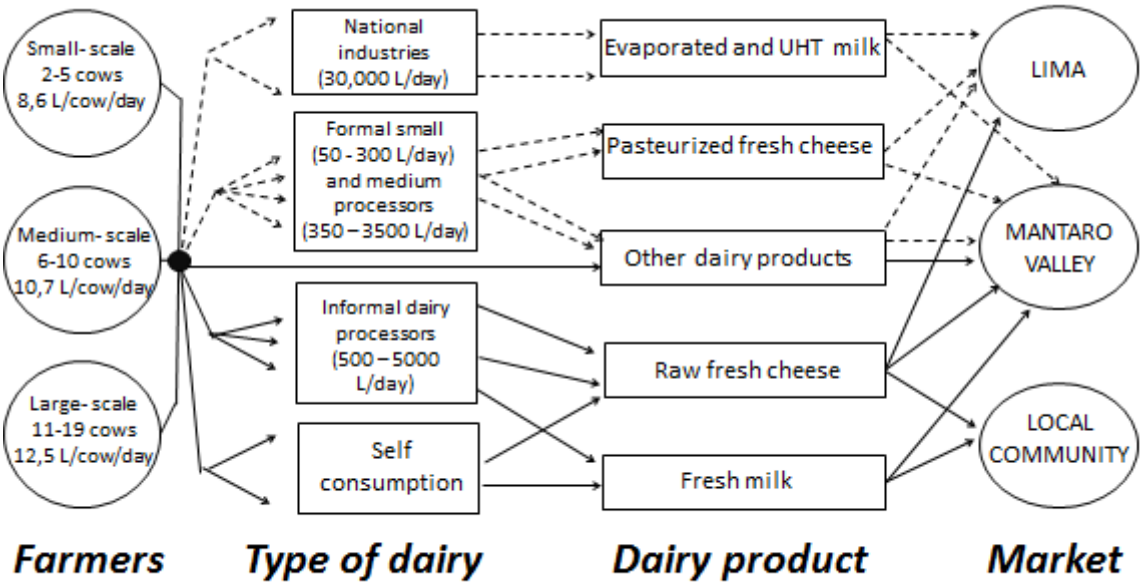



**Figure 5** Dairy supply channels at Mantaro Valley. National industries and formal small and medium processors provide products to formal markets (dotted arrows); whereas informal dairy processors deliver to informal markets (solid arrows).

*2.2.2. Relationship between stakeholders at Mantaro Valley*

The combination of channels and interdependency between stakeholders, both vertical among farmers, milk collectors, processors and retailers, and horizontal between processors, has an impact on the farmer-processor relationship and performance of the dairy supply chains in the area.

*a) Between dairy farmers:* Despite the fact that smallholder farmers account for around 60% of the dairy farms in the area, only 16% of farmers from the sample stated that they participated in a farmers' association. Indeed, there are few farmers' associations in Mantaro Valley. Previous bad experiences of collective organization such as the lack of trust among members, problems of mismanagement from the board members in charge of the association, and the obligation to work in the communal lands and disregard their own farms have limited small-holders' desire to be involved in farmers' associations.

Farmers' organizations started to increase in number when the National and Regional Government decided some years ago to support farmers with artificial insemination stations, training and subsidies provided they are grouped in such organizations. Nevertheless, farmers who do not participate in an association do not believe that these types of organizations can work by themselves. They think that their existence is dependent on external subsidies and interventions and that they will disappear when these projects finish.

*b) Small-holder farmers and dairy processors:* Milk transaction between small-holder farmers and dairy processors is closely to a "spot market" system, even when large quantities of milk are exchanged. Payment is usually done every weekend and by cash, since farmers do not have any type of contracts with their milk collectors or processors. Dairies which sell dairy products to the social program Qali Warma are an exception to this pattern. Qali Warma pays attractive prices to processors but only operates from April to December. This program requires dairy processors to have written contracts with farmers and fulfill high quality standards. Although processors delivering milk to Qali Warma pay 15-20% higher price per liter of milk when the program operates (from April to December), there is a constant risk that farmers will choose to break the contract and sell to parallel spot markets if the latter price rises above the contract price.

Milk price in the Mantaro Valley varies according to the time of the year and to the kind of processor. Formal processors pay 0.37 $/l in the rainy season and 0.40 $/l in the dry season, while informal ones pay 0.41$/l and 0.44 $/l respectively. This price difference reflects the strategy adopted by the informal sector in order to attract dairy farmers following the development of the formal sector in the area. The volume of milk bought at the farm gate and the distance between the farm and dairy also influence the final price. Only one multinational dairy company applies a payment system that includes quality criteria (level of total solids and microbiological content). It also adds the General Sales Taxes in the payment if its suppliers demand it, something scarcely asked for by farmers since most of them are not constituted as companies and prefer to remain informal and unknown by the national tax system.

*c) Small-holder farmers and milk collectors:* Farmers usually sell their milk to a collector who may retain their loyalty based on a better price, punctual payment, security of milk collection or services furnished. Without any formal arrangement, the trust and reliability between actors is central to securing commercialization and supply regularity on both sides. Indeed, farmers with less than 100 l/day deliver milk to the same collector every day. But medium and large-scale farmers with 100 up to 500 l/day prefer to deliver milk to several milk collectors/processors at the same time, in order to reduce the risk of non-collection when the demand decreases or of nonpayment if the collector disappears.

*d) Milk collectors and dairy processors:* Milk collectors deliver milk to dairy processors based on a verbal agreement. They can work for a processor by (i) collecting milk from farmers that have a prior arrangement with the dairy plant and receiving a fixed payment for the transportation of the milk from farm to plant gate; or (ii) collecting milk themselves and selling it at a given price per liter. Seventy-nine per cent of the collectors prefer this second alternative, using part of the milk collected every day to produce fresh cheeses and selling the rest of milk to other collectors or processors. This balance varies according to demand for cheese in Lima. For instance when cheese commercialization increases in January or between May and August (Figure 6), collectors process more milk on their own. However, they sell all the milk to an industry collection center when it decreases e.g. from

February until April. Consequently collection centers may expect some irregularities in the milk quantities supplied by a given collector during the year.

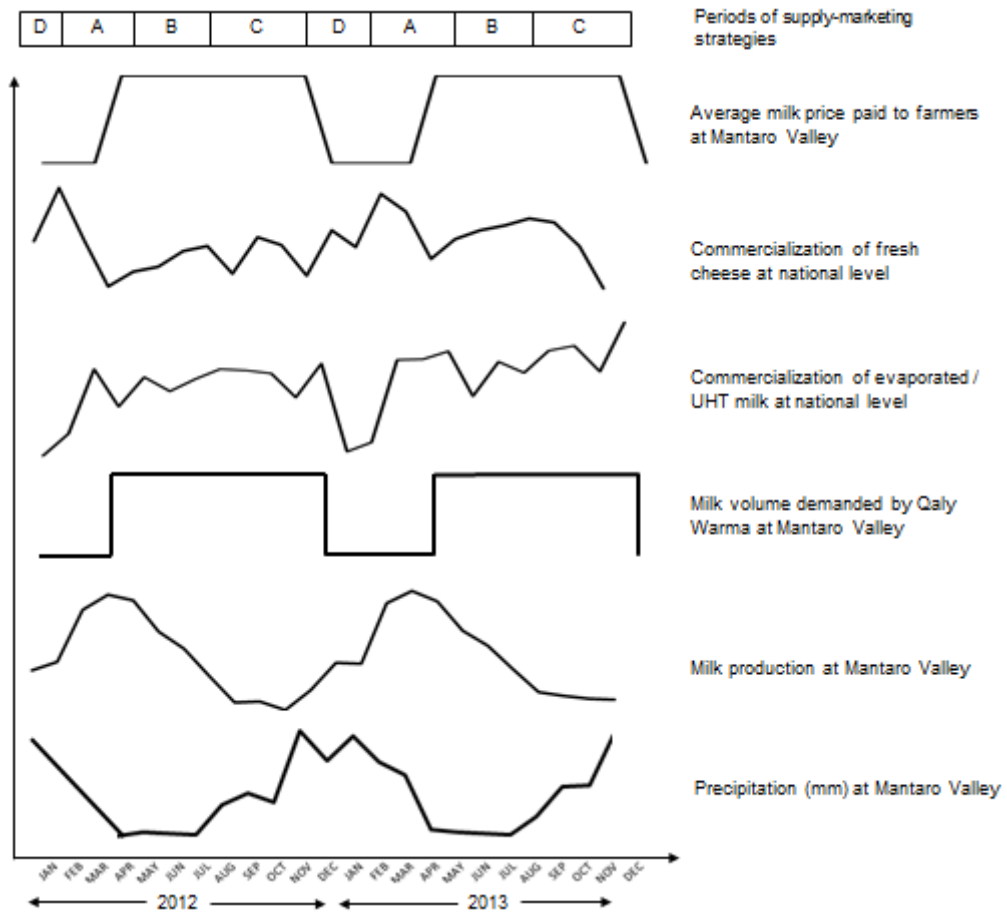



**Figure 6** Processors' strategies according to the period of a year, considering average level of dairy products commercialized at national level and milk price, milk production in the area and seasonal effect (precipitation) at Mantaro Valley. Data source: MINAG, 2014; SENAHMI; 2014.
A: Complementarity between processors during rainy season; B: Competition during dry season; C: Fluctuation in commercialization of dairy products due to low level of milk production; D: Competition at the beginning of the rainy season

In general dairy farmers, milk collectors and dairy processors at Mantaro Valley interact without formal contractual relations. The high milk demand in the area provides to stakeholders the possibility to change buyers if they are not satisfied with the milk price offered. Moreover, it reduces the pressure of dairy farmers and collectors to achieve high milk quality standards. This circumstance creates an unfavorable situation for formal dairy processors who supply dairy products to supermarkets and retailers demanding high quality products.

*d) Between dairy processors:* Milk quantities collected by the multinational dairy industries, local medium-scale dairies and artisanal cheese-makers varies throughout the year, according to the season (Figure 6), the quantity of milk they are able to collect and the market demands. These facts cause a constant flow of raw milk between stakeholders based on a mix of competition and complementary process. In the rainy season, milk production is high in the Valley due to good forage production in terms of quantity and quality. This situation favors, at the beginning of the season, a competition between processors for collecting the largest possible amount of milk (beginning of the period D; figure 6) and compensates for the smaller amount of dairy products produced during dry season.

Nevertheless, since informal and formal medium-scale processors are willing to buy only enough milk to satisfy their process capacity (end of the period D; Figure 6), the two multinational dairy companies are then able to collect more (by themselves or by buying from collectors) and use the extra milk to produce evaporated and UHT milk (Period A; Figure 6).

This flexibility between processors and the two multinational companies provide the security that dairy farmers require to sell their milk at a reasonable price, even in times of high production. It also reduces the risk of milk spoilage at farm level if there is a surplus of milk production that exceeds the manufacturing capacity of cheese makers. This particular situation provides an answer to the perishable feature of raw milk when the cold chain is broken, as is often the case in the Mantaro Valley. In the dry season, when milk production is lower, local processors compete to collect enough volume and offer higher prices per liter of milk than the two multinational dairy companies (Periods B and C; Figure 6). This result emphasizes the fact that milk prices paid to farmers in Mantaro Valley is more related to the production of milk in the area than the commercialization of dairy products in the capital. Moreover, the dynamic of milk distribution between processors allows the local production to be aligned with the variability of the demand for dairy products in Lima throughout the year, amplified locally by specific actors like Qali Warma during school periods.

In this context, the type of interaction between formal and informal sectors varies depending on the season of the year and the level of consumers demand. When the price of unpasteurized fresh cheese

is high in Lima, formal processors have to deal with the increased demand for milk from the informal sector (Periods B and C; Figure 6). They have to compete against informal processors for milk supply by offering a higher price to their farmers, which results in a reduction in profits. In contrast, the lack of label or origin differentiation makes informal processors sensitive to a decrease in retailers' demand, despite the fact that these processors align their processing and marketing practices with consumers' needs and their willingness to pay.

*2.2.3. Impact of the type of market supplied on economic performances of stakeholders*

Profits from farmers delivering milk to both formal and informal markets show differences according to the type of market channel supplied. Results obtained using a budget simulation tool for two specialized dairy farms (>60% of their land is used for forage crops), showed that profits per day of a large dairy farm (F1) are significantly higher than for a small-farmer (F2) due to the large amount of milk produced. However, large farmers normally have higher milk production costs and, as a consequence, lower profit per liter of milk produced compared to small-farmers (F2). F1 profit per liter is increased by nearly a factor of three if they sell to informal processors and can be doubled in the case of F2. This result is explained because F2 have already better profits per liter than F1 when they sell to formal processors (0.082 vs. 0.030 respectively). In any case, the higher profit in the formal chain corresponds to their positive GST balance (they sell more than they buy). Therefore farmers do not get any advantage from being part of the formal sector (Table 5). Small differences in the farmers' profits per day were observed when the seasonality effect was considered. In the case of F1 only, a reduction in milk production was significantly compensated by an increased price during the dry season.

**Table 5:** Farmers' production costs, profits per liter and per day ($) when they sell to formal and informal dairy processors, and General Sales Taxes (GST) balance per liter of milk at Mantaro Valley*

| Farmer | Farmers' production cost ($/l) | **Formal processor** | | **Informal processor** | | GST Balance ($/l) | |
|---|---|---|---|---|---|---|---|
| | | Profit per liter ($) | Profit per day ($) | Profit per liter ($) | Profit per day ($) | Rainy season | Dry season |
| Farmer F1** | 0,328 | 0,030 | 7,111 | 0,086 | 20,711 | 0,014 | 0,020 |
| Farmer F2*** | 0,267 | 0,082 | 2,960 | 0,139 | 5,000 | 0,022 | 0,027 |

GST: General Sales Taxes

* Results obtained using a budget simulation tool developed with Excel 2010, considering average values for each type of farm.
**F1 = Large-scale highly productive farm: 7-10 has, 20 dairy cattle, Holstein breed, 45-55% concentrate purchased, milk production of 14-16 lt/cow/day
***F2 = Small-scale highly productive farm: 1-6 has, 3-9 dairy cattle, crossbreed, 10-70% concentrate purchased, milk production of 10-12 lt/cow/day

Compared to formal processers, informal processors take advantage of the limited demand for quality controls in the supply chain and the reduced transport and marketing costs. They collect the milk by their own mini trucks, do not label their products and do not refrigerate their dairy products. Moreover, they have lower fixed costs compared to the formal processors. Additionally, the formal processors' profit decreases to 0,061 $/l when they get milk from farmers who are not interested in paying GST. In this scenario the formal processors cannot recover the GST through the milk price charged to the consumer (Table 6). Informal processors achieve a better profit per liter of milk than formal ones in every scenario. Indeed their cost difference with the formal chain (after GST deduction) is only 0.042 $/l while their product difference is 0.078 $/l. Informal cheese-makers value milk at 0.472 $/l compared to 0.514 $/l for formal processors before GST deduction.

**Table 6:** Processors' production costs and profits, and General Sales Taxes (GST) balance per liter of milk at Mantaro Valley

| Processor | Processors' production cost ($/l) | Processors' profit ($/l) | Processors' profit per day ($)**** | GST Balance ($/l) | |
|---|---|---|---|---|---|
| | | | | Rainy season | Dry season |
| Processor F* | 0,432 | 0,137 | 95,9 | 0,036 | 0,036 |
| Processor F** | 0,514 | 0,061 | 42,7 | 0,078 | 0,078 |
| Processor I*** | 0,472 | 0,195 | 136,5 | | |

*Formal dairy buying milk from a formal farmer. For 8 litres of milk at 11.4% TS (total solids) required for producing 1 kg of pressed cheese sold 5.50 $/kg and GST discount on sales and purchases including milk
**Formal dairy buying milk from an informal farmer. For 8 litres of milk at 11.4% TS required for producing 1 kg of pressed cheese sold 5.50 $/kg and GST discount excluding milk
*** Informal cheese maker. For 5 litres of milk at 11.4% TS required for producing 1 kg of fresh cheese sold 3.30 $/kg and no GST discount
**** Considering an average milk collection of 700 liters/day
GST: General Sales Taxes

So, in the current context of production costs and milk/cheese price structure, the informal chain achieves better profits per liter of milk than the formal one. In the context of competition for milk at

farm level, informal processors can then offer better milk prices to farmers, especially during the dry season when milk production is lower. This economic result pushes many stakeholders to remain in the informal sector, especially since GST management demands more administrative work.

## 2.3. Discussion

### *2.3.1. Ensuring a constant milk supply: Spot market or formal contracts?*

Stakeholders' preference to interact without formal agreements is explained by the high demand of milk in the area and the benefits that dairy farmers and processors, especially from the informal sector, receive for trading informally, i.e. reduction in their operational costs, reduction in entry costs, and the ability to offer milk and dairy products at lower prices. Indeed, it allows smallholder farms and artisanal cheese-makers to be included in the dairy sector without making big investments. This situation generates a type of relationship between stakeholders where milk supplied is adjusted through verbal arrangements with no incentive for farmers to improve milk quality or for processors to support farmers technically. Although no formal contracts are applied, other types of strategies are used in Mantaro Valley to ensure a constant milk supply. Strategies applied worldwide such as offering attractive prices to farmers (Mdoe and Wiggins, 1996) or avoiding farm payment delays in order to secure suppliers (Fałkowski, 2012; Dries et al., 2009) seems to be also very effective in this particular context.

According to our results, organizational strategies like formal contracts are difficult to implement in Mantaro Valley. Contract farming can provide benefits to dairy stakeholders. Nevertheless, the co-existence of a dual market with the presence of one sector which is less demanding in terms of quality, and the constant risk that farmers would prefer to sell to parallel spot markets if the milk price offered rises above the contract price, compound the main difficulties for such implementation. Some disincentives for dairy processors to contract with smallholders are associated with the transaction costs related with providing inputs, credit, extension services, and product collection and grading (Key and Runsten, 1999). Dairies which sell to the Qali Warma national program are the only ones involved in a formal agreement between its milk suppliers. However, a constraint of this program is that it creates uncertainty between farmers and processors during the time of school holidays, as the

program operates only from April to December. Formal contracts can be addressed by supporting the establishment of farmers' associations as a way to manage and control milk quality supplies of farmers' members who deliver small quantities of milk every day. Nevertheless, it means building trust among farmers, which is still problematic in the Mantaro Valley for historical reasons.

*2.3.2. Milk quality as key point of differentiation between formal and informal sector:*

The informal sector in developing countries provides dairy products to poor urban areas (Padilla et al., 2004) and small-scale farmers are favored, since they do not have the pressure to adopt costly quality control measures that are not usually compensated by a higher milk price (Valeeva et al., 2007). In the Peruvian case, the poor State control (Delgado and Maurtua, 2003) and the low economic status of the majority of consumers who remain exceptionally poor by any standard seems to explain the important presence of the informal sector in Lima. This situation disfavors the formal sector, which needs to fulfill market requirements and supply a constant quality of dairy products while competing with the informal sector for a constant milk supply in the area. Thus, the co-existence of dual markets with a differentiation in consumers' demands and without any type of regulation provides fragility to the whole sector: The formal sector faces difficulties in achieving high milk quality standards and the informal sector earns more profits but remains sensitive to State controls.

In this context, high levels of milk quality can be difficult to achieve by formal dairy processors. Indeed, pushing milk suppliers too hard to fulfill milk quality standards without rewarding their performance could make them move to processors with less interest in quality aspects of milk, affecting at the end processors' level of milk quantities collected. Milk payment in the Mantaro Valley, as in some other cases (Espinoza-Ortega et al., 2007; Gorton et al., 2006) is still based on a flat price changing from one processor to another according to the supply and demand balance during the year and the competition between them. Thus, an innovative way to ensure milk supply and high levels of milk quality in Mantaro Valley can be achieved by the implementation of payment systems that guarantee a win-win scenario for small-scale farmers and dairy processors; it means satisfying both their economic expectations for providing or buying milk. In this respect, alternative payment systems based on quality should be explored jointly with the stakeholders.

***Chapter 3:*** *Effects of the application of husbandry / manufacturing practices and the introduction of new dairy technology on the general status of raw milk quality*

This chapter analyzes the current milk quality status, the effect of stakeholders' practices on milk quality and the changes in the perception of milk quality after the introduction of ultrasound milk analyzer equipment (UMA) in Mantaro Valley. Milk chemical and hygienic quality in Mantaro Valley is highly variable at farm level and processor gate. Few husbandry practices are frequently applied and low concern about the effects of these practices on the final product explains the lack of an established milk quality management program in the study area. Stakeholders showed interest and desire to learn more about milk quality after the introduction of UMA. Nevertheless, some constraints to interpreting the outputs from UMA created conflicts between farmers and processors. Results showed that permanent use of some husbandry practices can help dairy farmers improve their current milk quality status in the study area, but the time and cost of the implementation of these practices need to be somehow rewarded by dairy processors. Moreover, the successful implementation of new technologies like UMA requires a better establishment of coordination process between both stakeholders. More detail information is available in volume 2 of the present document.

### 3.1 Materials and methods

Data was obtained from a sample of 20 smallholder dairy producers, 3 dairy processors and a collection center, in order to get a detailed evaluation of milk quality in the area. Dairy processors varied in terms of volume of milk processed, technological level and market orientation. Dairy farmers were selected taking into account the large diversity of herd size, average milk production and type of milking system. The farm sample structure included 60% of small-scale farmers (production of 20-50 l/farm/day and 8.5 l/cow/day), 30% of medium-scale farmers (production of 50-100 l/farm/day and 10.5 l/cow/day) and 10% of large-scale farmers (production exceeding 100 l/farm/day and 12.0 l/cow/day). The last two categories were regrouped for analytical purposes.

Data were collected over 12 months from April 2012 to March 2013. Every month milk samples were taken from bulk tanks of every selected farm and dairy processor. In both cases, chemical milk

composition, somatic cells counts and hygienic status were determined using portable equipment. Average milk chemical composition (percentage of milk fat, milk protein, total solids, lactose and minerals) and physical milk properties (density, water added) of each milk sample was measured with Master Eco® ultrasound milk analyzer (http://www.milkotester.com/data/Master%20Eco.pdf). The analyzer was calibrated every month using reference AOAC methods (Helrich, 1990). Somatic cell count (SCC) was obtained with the indirect on-farm test Porta SCC®, which converts results of an enzymatic reaction into an estimated SCC (Rodrigues et al., 2009). Hygienic status, measured with the Methylene blue reduction test (MBRT), was performed according to the IDF (1990) protocol. MBRT is based on the time milk takes to decolorize methylene blue by the activity of the reducing bacteria present in the milk. The more contaminated the milk, the faster color changes from blue to white.

Bulk milk samples (50ml) were taken once per month from each of the 20 farmers. For each farmer, samples (morning and afternoon) were collected and analyzed from bulk churns at the end of each milking, and then pooled to obtain an average daily value. A similar sampling protocol was performed during a period of one week every month to the milk from the processors' truck and the independent collector of each of the 3 processors evaluated. Evaluation of milk hygienic deterioration from farm gate to plant gate was performed on one dairy farm per processor. Samples from the same milk were taken at three different times: the first one in the afternoon on day-1; the second one the next morning when the milk was collected at farm gate; and the last one when the milk arrived at plant gate. Along with milk analyses, the farmer's husbandry practices were recorded (Annex 3) once a month and compared to a set of recommended management practices based on the literature (Table 8)

A complementary evaluation was done to determine changes in the perception of milk quality, based on the introduction of the ultrasound milk analyzer (UMA) in the production system. Farmers were split in small-scale and large-scale farmers to evaluate differences in understanding milk quality issues. As this analysis was conducted in situ, it was possible to record stakeholders' reactions about the UMA and obtain measurements that could be immediately discussed with farmers and processors. Concurrently, 10 dairies who bought ultrasound milk analyzer equipment (UMA) after our intervention were interviewed to know what they are doing with it. Information about the use of the equipment, frequency of the use and the main constraints they are facing using the UMA were obtained (Annex 4).

Descriptive statistics (average, standard deviation and correlations) for analyzing milk quality composition and its relationship with farmers' practices were carried out considering the 12-month dataset, which included 238 milk samples at farm level and 480 at plant gate. The XLStat™2012.6.01 software (Addinsoft, Paris, France) was used for that purpose. For the analysis of the introduction of UMA, average and percentages were carried out using Microsoft Excel™ 2010.

### 3.2. Synthesis of the Results

#### *3.2.1. Milk quality status in Mantaro Valley*

Milk quality in Mantaro Valley varied largely within the sample, highlighting the fact that processors had to face a large diversity of batch quality among farmers and from one day to the next. Average milk chemical quality parameters were found to be acceptable compared to the values generally recommended for this product by Peruvian legislation (Table 7). However, milk fat content, MBRT and average somatic cells counts showed the highest variability.

**Table 7** Descriptive statistics of the main variables describing milk quality at farm level (n=238) and recommended values for Peru

| | TF (g/kg) | SNF (g/kg) | Total Solids (g/kg) | TP (g/kg) | MBRT grade (hour) | Somatic Cells Count (cells / ml) |
|---|---|---|---|---|---|---|
| Recommended Peruvian values | 32 | 82 | 114 | 32 | 4,0 | 200000 |
| Whole sample (n=238) | | | | | | |
| Average | 37 | 82 | 119 | 34 | 5.4 | 447231 |
| SD | 0.4 | 0.3 | 0.5 | 0.2 | 1.2 | 449049 |
| CV | 10.9 | 3.8 | 4.6 | 5.8 | 23.0 | 100 |
| Small farms (n=154) | | | | | | |
| Average | 37 | 82 | 119 | 34 | 5.7 | 440821 |
| SD | 0.4 | 0.3 | 0.6 | 0.2 | 0.7 | 505630 |
| CV | 10.9 | 3.8 | 5.0 | 5.8 | 12.2 | 115 |
| Large farms (n=84) | | | | | | |
| Average | 37 | 81 | 119 | 34 | 4.7 | 458982 |
| SD | 0.3 | 0.3 | 0.4 | 0.2 | 1.7 | 322930 |
| CV | 8.1 | 3.7 | 3.4 | 5.8 | 36.2 | 70 |

TF: Total fat SNF: Non-fat solids TP: Total protein CV: coefficient of variation
MBRT: Methylene blue reduction test SD: standard deviation

Large-scale farmers showed significantly poorer milk hygiene than smallholder farmers, with respectively 4.7 and 5.7 mean MBRT value (p value < 0.0001), and the average SCC exceeded the upper limit of international standards, since only one third of milk samples were below 200,000 cells / ml. Milk Total Solids (TS) and MBRT were affected by the season due to rainfall and temperature variations. During the dry season, when rainfall and temperature are low, TS decreases due to the limited availability of good quality forage, while hygiene improves because of lower bacterial contamination (Figure 7).

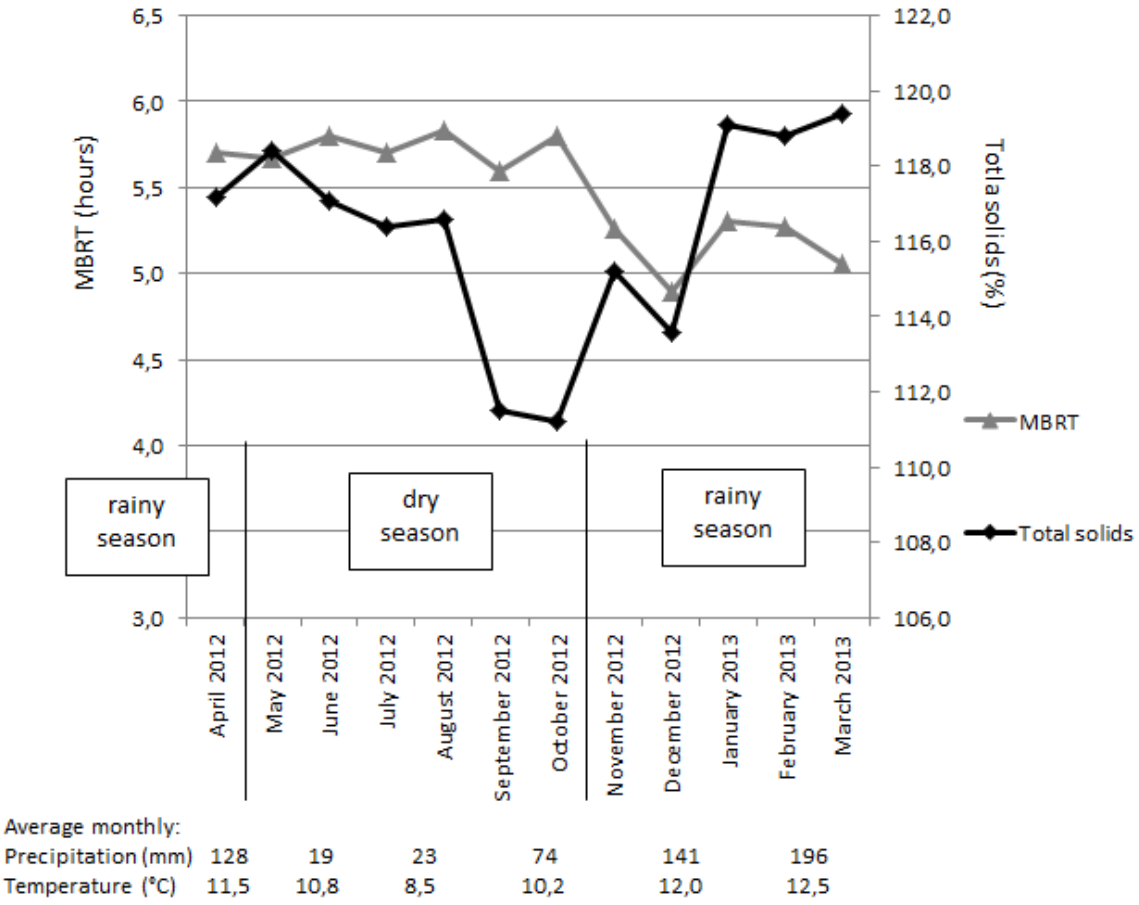



**Figure 7** Methylene blue reduction test (hours) and total solids at farm level (%). Dry season = no rain and low temperature; rainy season: rainfall and high temperature

*3.2.2. Effects of stakeholders' practices on raw milk quality*

One feeding practice out of five evaluated and eight milking and sanitary practices out of twenty one were identified as frequently applied, i.e. exceeding half of monthly observations during the 12-month

monitoring (Table 8). Feeding practices were mainly based on cut green forage distributed at stable and grazing on plots, with an average of 15.9 and 13.6 kg/cow/day of dry matter intake per diet for large-scale and small-scale farmers respectively.

**Table 8** List of husbandry practices and their application according to farm size (% of monthly observations during the 12-month monitoring period)

| Practices | Small farm (n=154) | Large farm (n=84) | Total (n=238) |
|---|---|---|---|
| *Feeding:* | | | |
| Regular use of: | | | |
| -Home-made concentrate | 10 | 40 | 21 |
| -Mineral salt | 90 | 70 | **83** |
| -Silage | 0 | 30 | 11 |
| -Range pasture | 10 | 0 | 6 |
| -Cereal stover | 20 | 30 | 24 |
| *Milking* | | | |
| Keep an updated notebook of treatment records | 70 | 70 | **70** |
| Gather the cows in a waiting yard before milking | 0 | 40 | 14 |
| Clean frequently the barn | 80 | 60 | **73** |
| Use of milking parlor | 30 | 80 | **50** |
| Have a milk-cooling system after milking | 20 | 40 | 27 |
| Udder examined before milking | 30 | 30 | 30 |
| Good cleanliness of milk churns before milking | 100 | 100 | **100** |
| Milking by mechanical means | 0 | 50 | 17 |
| Udder washed before milking | 90 | 90 | **90** |
| The washing water contains disinfectant | 20 | 10 | 16 |
| The udder is dried after washing | 50 | 60 | **54** |
| Frequent training of personnel | 10 | 20 | 14 |
| Predip | 0 | 0 | 0 |
| Forestrip | 20 | 40 | 27 |
| Post-milking teat dipping | 10 | 20 | 14 |
| Use California mastitis test | 0 | 30 | 12 |
| Wear gloves | 0 | 10 | 4 |
| Milk is filtered before depositing in churns | 100 | 100 | **100** |
| Avoid cow restraints during milking | 10 | 10 | 10 |
| Use of potable source of water | 70 | 90 | **77** |
| Average cow dirtiness score | 2.6 | 2.4 | 2.5 |

In bold practices exceeding 50% of observations.

Farmers did not calculate diets based on targeted production levels of milk. The amounts distributed were linked to the availability of green forage with some diversity between farms in terms of forage quality and quantity (Table 9). Mineral salt was frequently applied, while the daily supply of concentrates was generally limited to between 1.5 and 2 kg of wheat bran per cow. However, large-scale farmers were more concerned with providing feed by-products and a constant source of maize stems than smallholders were, which was reflected in higher levels of net energy for lactation provided (23.7 vs. 20.4 Mcal/cow/day in average respectively).

**Table 9** Examples of diets supplied by three small-scale and three large-scale farmers

| | SS1 | SS2 | SS3 | LS1 | LS2 | LS3 |
|---|---|---|---|---|---|---|
| Forage (kg DM/cow/day) | | | | | | |
| Red clover | 2.7 | 3.1 | 1.8 | 1.4 | 2.7 | - |
| Ryegrass | 5.4 | 4.5 | 2.7 | 3.6 | 2.7 | 3.6 |
| Oat forage | - | 2.5 | 6.2 | 3.1 | 1.6 | 6.2 |
| Corn stover | - | - | 2.7 | 5.4 | 2.7 | 4.1 |
| Alfalfa | 2.9 | 1.9 | 1.0 | 0.5 | 1.9 | 1.0 |
| Artichoke by-product | - | - | - | | 0.7 | |
| Concentrates (kg DM/cow/day) | | | | | | |
| Wheat bran | 0.9 | 1.8 | 1.8 | 0.5 | 1.8 | 2.4 |
| Cotton seed | - | - | - | - | - | 0.4 |
| Maize grain | - | - | - | - | - | 0.4 |
| Soybean meal | - | - | - | - | - | 0.5 |
| Distiller's dried grains with solubles | - | - | - | - | 0.9 | - |
| TOTAL | 11.9 | 13.8 | 16.2 | 14.5 | 15.0 | 18.6 |
| Energy in the Diet (Mcal) | *18.3* | *20.7* | *23.3* | *20.6* | *23.0* | *27.1* |

SS: Small-scale farmer LS: Large-scale farmer DM: Dry matter

Milking and sanitary practices frequently adopted by farmers included the use of a milking parlor, access to a potable source of water, cleaning animal housing at least once per day and cleaning churns before milking. Nevertheless, milk churns were generally cleaned without detergent and milking parlors consisted of small spaces of concrete flooring in the housing barn. Other basic practices were applied such as washing the cow's udder before milking and drying it after washing, filtering the milk before depositing in churns and keeping an updated notebook of treatment records. Some practices varied according to herd size. Large farmers showed more interest in applying practices that demand

higher economic investments. Thirty percent of large-scale farmers tested possible subclinical mastitis cases at least once per year, and half of them milked by mechanical means, had a milking parlor, had a cold system after milking and utilized a waiting yard where cows rested before milking. Small-scale farmers usually cleaned the barn more often than large-scale farms, since they milked their cows in the same small space where the animals also rest.

Milk chemical composition was not significantly correlated to feed energy and protein available in the diet on the whole farm sample (Table 10). Indeed, linking net energy provided by the diet, milk fat content and dominant farm breed leads to a large range of results with Brown Swiss farms showing a much better efficiency in transforming energy in milk fat. This result highlights the difficulty in establishing clear feeding strategies to achieve higher values of milk chemical components in the feeding conditions prevailing in the area studied.

**Table 10** Correlations between average milk composition and average nutrients from diets supplied at Mantaro Valley (n=20) from pooled results over 12 month period with average of 12 observations each farm.

| | Milk composition | | |
|---|---|---|---|
| | Total solids (g/kg) | Total fat (g/kg) | Total protein (g/kg) |
| Forage nutrients | | | |
| Energy (MCal) | 0.132 | 0.302 | -0.103 |
| Protein (g/kg) | 0.020 | -0.020 | -0.110 |

r values < 0.67 for α=0.05

Correlations were calculated between milking practices and the milk hygienic status of raw milk (Table 11). In contrast to expected results, the access to infrastructure and milking equipment found in large-scale farms did not mean better milk hygienic status. Indeed, gathering cows in a waiting yard, use of a milking parlor or milking by mechanical means were negatively correlated with values of MBRT. The poor cleaning regime of these buildings (less than once a day), or a lack of a deep cleaning of milking equipment could explain this result. On the contrary, some hygienic practices such as cleaning animal houses at least once per day, using a disinfectant to clean the udder before milking and filtering milk before pouring it in churns, was more effective in improving MBRT. Similarly, values of milk somatic cells showed a positive correlation to low cow dirtiness score. Moreover, a decreased level of SCC was also obtained when the animal house was cleaned at least once per day and when dairy farms had permanent access to a source of potable water.

**Table 11** Correlations* between husbandry practices and hygienic status of raw milk (n=238)

| Husbandry practices | MBRT | SCC |
|---|---|---|
| Gather the cows in a waiting yard before milking | ***-0.488*** | 0.084 |
| Clean animal house | *0.161* | ***-0.178*** |
| Use of milking parlor | ***-0.248*** | -0,104 |
| Cows are milked by machine | ***-0.387*** | -0.022 |
| The washing water contains disinfectant | *0.141* | 0.080 |
| Milk is filtered before depositing in churns | ***0.256*** | -0.007 |
| Use of a potable source of water for cleaning | -0.052 | **-0.302** |
| Average cow dirtiness score | -0.072 | *0.152* |

*In italic: values significant for α=0.05 In bold and italic: values significant for α=0.01

Processors in the Mantaro Valley collect milk personally at the farm gate, or by buying milk collected by independent collectors. These two logistical options affect milk quality differently according to the component considered. Milk chemical quality parameters were quite similar in both cases (Table 12), as this component is quite stable along the chain and since farmers are not selected by buyers according to their TS performances.

Milk collected by processors themselves showed lower SCC than milk collected by independent collectors. Indeed, dairy processors had more control of the milk collected, since they usually dealt with less than 30 farmers whose milking practices they knew, compared with independent collectors who collected milk from more than 100 farmers.

**Table 12** Comparison of milk quality values at processor's gate according to the plant supplier

| | | Processor own supply (n=178) | Independent collector (n=155) |
|---|---|---|---|
| Total Solids (g/kg) | | | |
| | average | 116 | 116 |
| | CV | 4.1 | 4.2 |
| SCC (cells/ml) | | | |
| | average | 283505 | 425683 |
| | CV | 79 | 65 |
| MBRT (hours) | | | |
| | average | 2.2 | 1.9 |
| | CV | 63 | 72 |

CV: coefficient of variation (%)

In both cases the absence of a cold chain from farm to plant gate affects hygiene quality, based on MBRT. Indeed, while fresh milk measured at farm level showed an average MBRT time of 460 minutes, it decreased to 240 minutes after almost 12 hours of storage at Mantaro Valley's ambient temperature (Figure 8).

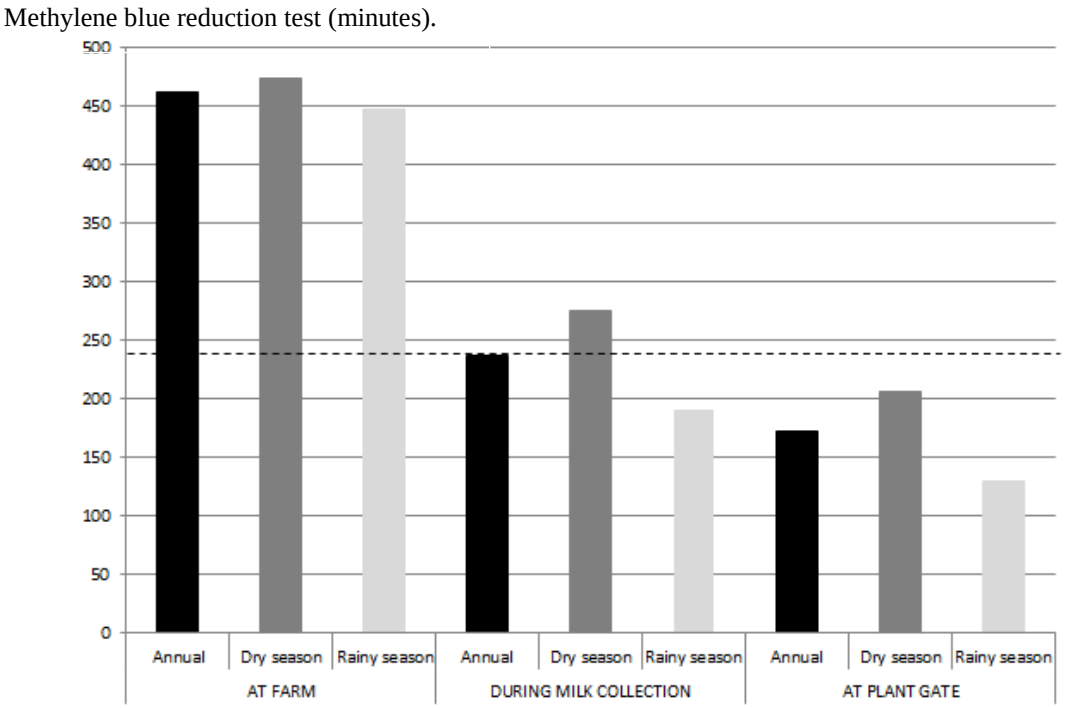



**Figure 8** Variation in hygienic milk quality at Mantaro Valley. Milk samples were analysed at three times separately: At farm level, during milk collection after almost 12 hours under Mantaro Valley's conditions, and at plant gate; using methylene blue reduction test (minutes). Black line: minimum recommended value (Suggested values based on Norma Técnica Peruana 202.001 – INDECOPI and R.M. 591 – 2008/MINSA).

The degradation process continued from milk collection at farm gate to its delivery at plant gate, with one hour of extra reduction (180 minutes). These results highlighted the importance for both processors and collectors to better manage logistics between farm and plant in order to reduce degradation of milk. The current logistical organization, based on one daily collection by various vehicles from bicycles to medium-sized trucks, and with plastic containers where milk from various farmers is mixed when individual deliveries are too small, will not improve milk quality.

*3.2.3. Implications of introducing a new dairy technology on small-scale dairy production*

The first demonstration of the technical innovation received positive reactions from small-scale farmers and dairy processors. Most of them were ready to buy a UMA, since both groups saw the opportunity to better monitor the quality of the deliveries. Processors identified the possibility to change their delivery system in order to individually evaluate each farmer at the plant gate and separate farmers with problems, whereas farmers suggested comparing quality per cow or throughout the year. This result illustrates the capacity of this quite simple but powerful technology to make stakeholders react. Nevertheless, general lack of knowledge regarding the use of the UMA was observed at Mantaro Valley after the dissemination of the technical innovation.

Differences in understanding milk chemical values provided by UMA varied according to the size of the dairy farm (Figure 9). Indeed, the first reports provided by the equipment were not clearly understood by most of small-scale dairy farmers (more than 80%), but easily interpreted by the majority of large-scale farmers (more than 70%). All the large-scale farmers were able to explain in advance possible relationships between milk chemical values and their husbandry practices compared to less than 40% in the case of small-scale farmers. The previous participation of large-scale farmers in a milk quality based payment system played an important role in this result.

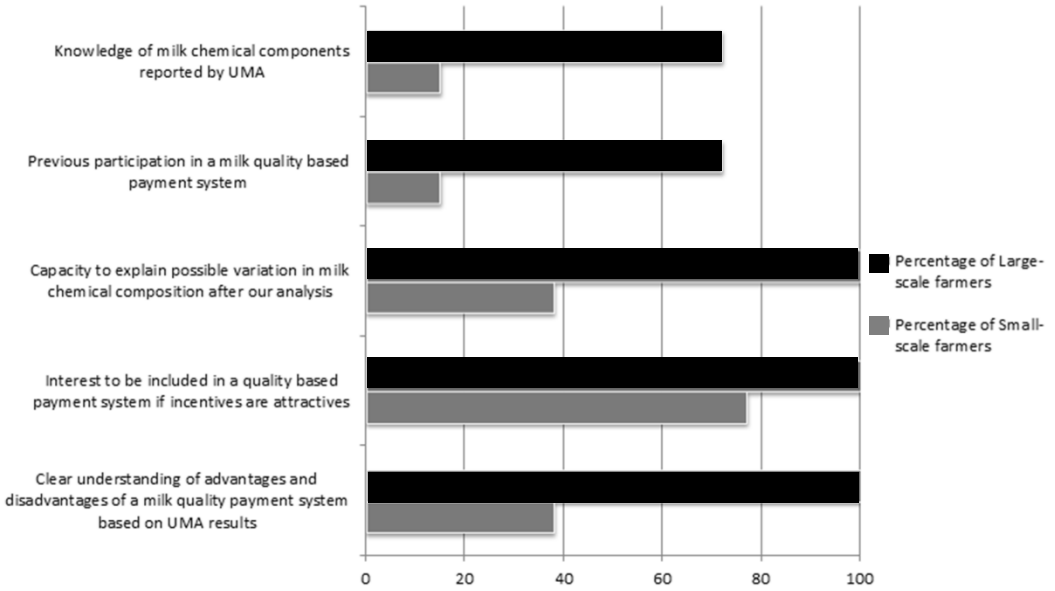



**Figure 9:** Different reactions about the use of UMA according to the scale of the dairy farmers

Both small- and large-scale farmers expressed their desire to participate in quality based payment systems. However, only large farmers reported a clear understanding of advantages and disadvantages of a quality payment system based on UMA results. Sixty percent of small-scale farmers were not able to identify arguments against it, highlighting the risks of failure in implementing a milk quality payment system in the study area if there is not a clear explanation of the rules (premiums and penalties) to all the stakeholders.

From the processor side, the main reason for purchasing the MasterEco was to detect milk adulteration (usually a mix of milk and water or milk and whey) (Figure 10). Although the analyzer provides a range of variables that can be used for improving their manufacturing process or providing support to dairy farmers, dairy processors were mostly focused on evaluating density and water added, both because of their main adulteration concern. In this respect, the lack of training when dairy processors received the device seems to explain the poor interpretation of the milk chemical parameters.

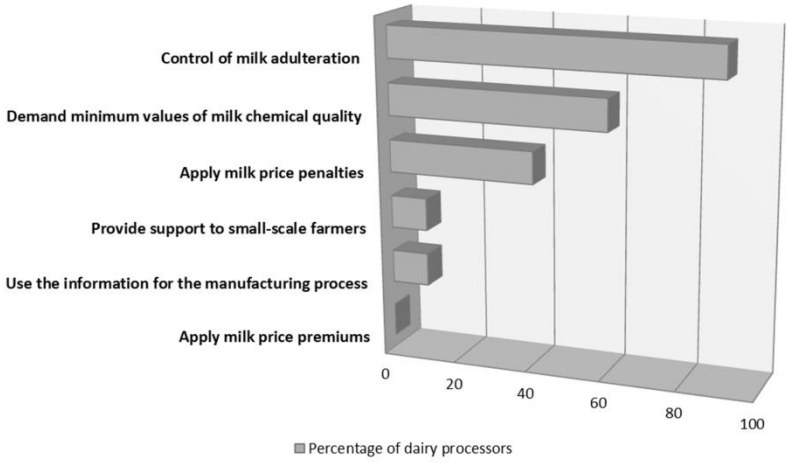



**Figure 10:** Use of UMA by dairy processors in Mantaro Valley

The use of the equipment in the study area enabled some dairy processors to get rid of farmers or collectors delivering poor quality milk. However, a lack of discussion of the results with the rest of stakeholders created conflicts between farmers and processors, such as the discomfort of from some milk suppliers and the movement of some dairy farmers to less demanding dairy processors. These conflicts also led to a reduction in the frequency of use of the UMA. Indeed, at the time of our

intervention forty percent of processors were using UMA less than once per month, 20% once every two weeks and only 10% daily. Others factors limiting the frequent use of the equipment were the processor's' concern about the possible disfunctioning or discalibration of the equipment, and the payment of unnecessary extra cost for the maintenance of the equipment.

The use of UMA in the implementation of milk quality payment systems was suggested to dairy processors. They expressed a contrasting point of view. Most of them agreed that implementing quality controls and milk quality payment systems will allow them to have the security that they are paying a profitable price for the milk they are buying. Nevertheless, their main concern was that it will probably demand trained personnel, time and a better management of the information, three things with which small-scale dairy processors still have problems. In-depth analysis of milk quality results could improve small-scale dairy processors' performances. However, they do not have adapted tools to help them make the best decisions.

### 3.3. Discussion

#### *3.3.1. Dealing with a large milk quality variability*

Results regarding milk quality analysis showed the large variation in milk composition and hygienic values that exist in Mantaro Valley. This variability also emphasizes the importance of having adequate milk quality controls and sufficient knowledge for understanding the impact of milk quality parameters on the manufacturing process. Hygienic status of raw milk at farm level was often good compared to other contexts in developing countries where hygienic contamination is a critical issue (Sraïri et al., 2006; Grimaud et al., 2007). But the considerable deterioration of hygienic milk quality during milk collection indicated the poor hygienic management and lack of interest in the hygienic status of raw milk (Koussou and Grimaud, 2007; Srairi et al., 2006). Poor processors' logistic aspects such as the use of unclean containers (Kivaria et al., 2006), mixing fresh milk and milk from the previous afternoon (Millogo et al., 2008); a longer time between fresh milk collection at farm gate and plant delivery (Gran et al., 2002), and lack of cooling facilities during the rainy season when the temperature is warmer (Grimaud et al., 2009) increased milk deterioration of the whole batch. This

whole situation mainly affects formal dairy processors who need to manufacture good quality dairy products. Thus, they are obliged to improve milk collection logistics in order to ensure the safety of their dairy products, reduce the degradation of milk batches and justify the effort to push dairy farmers to improve hygienic milk quality.

Chemical quality variability is partly explained by the effect of climatic conditions on farmers' feeding strategies (Larsen et al., 2010), which influence farmer's capacity to effectively react to the imbalance between stocking rates and forage production. Indeed, low availability of good quality fodder, especially during the dry season, plus poor animal genetics (Bartl et al., 2009) and lack of capital, limit smallholders' capacity to permanently invest in animals, milking machines, purchase of land, or new technologies (Solano et al., 2000). In this respect, small-scale farmers could improve milk chemical quality through the implementation of collective actions between famers i.e. creating farmers' associations or cooperatives (Dulcire et al.,, 2012), which may support the common investment in land and technology for the benefit of all the members.

*3.3.2. Constraints of introducing technical innovations*

Literature on agriculture highlights two major drivers of successful technology adoption in developing countries: (i) the availability and affordability of technologies; and (ii) stakeholders expectations that adoption will remain profitable (Kasirye, 2013). Other factors affecting technology use are related to characteristics of the technology and objectives of the stakeholders (Doss, 2006). Despite the fact that the UMA proved to be very easy to handle, its introduction at Mantaro Valley was not supported adequately with sufficient information about milk quality issues and management practices. Moreover, implementing milk quality controls based on UMA results were not considered attractive to stakeholders, since farmers did not receive incentives for improving their current status. Indeed, dairy processors' objectives were oriented mainly towards a strict control of milk quality adulteration, instead of building milk quality payment systems to attract new dairy suppliers, motivate the rest of milk producers to 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).

*3.3.3. Clarifying stakeholders' perception of milk quality*

Results showed poor knowledge about milk quality in the study area, similar to other dairy supply chains in developing countries where the informal sector is predominant (Srairi et al., 2006). Indeed, quality was not a concept considered important by stakeholders when this study started. But, measuring quality directly on farms and dairy plants helped both farmers and processors to clarify their ideas about this concept. Dairy processors started to be more conscious about the need to individually identify each farmer at plant gate and to demand better milk quality, but still without realizing the impact that improving milk quality standards can provide to their business. For these reasons, processors were not ready to pay more for better milk quality even when asked by farmers and no main changes were observed during the 12-month monitoring of milk quality in the area. In that respect, the design of a simulation tool could provide the support to show dairy processors the benefits of implementing quality controls and quality based payment systems.

***Chapter 4:*** *Use of a simulation tool to support small-scale dairy plants in selecting market orientations and milk payment systems.*

The present chapter shows the usage of a decision support system which deal with strategic issues that dairy processors face in interaction with their suppliers and buyers, i.e. selecting their product portfolio according to markets opportunities and designing milk payment systems encouraging dairy farmers to supply good quantity and quality milk throughout the year. The approach tested with two small-scale dairy plants in the Mantaro Valley (Peru) showed that (i) they could increase their total profits by modifying their current portfolio towards higher value products, assuming milk delivered to the plant attains a given quality; (ii) they do not pay correctly farmers who deliver good quality milk and overpay some bad quality milk; (iii) their profits would not be affected by adopting a payment system based on milk quality. More detail information is available in volume 2 of the present document.

### 4.1 Materials and Methods

This study was conducted in two steps. The first one consisted in designing and developing a simulation tool called DairyPlant able to calculate the processor's profits and farmers' gross products corresponding to a given configuration of dairy plant and of milk payment system. The second one focused on testing DairyPlant with two small-scale dairies, by supporting them in better selecting their market orientations and evaluating the impacts of implementing new milk payment systems in their current supply and processing systems.

DairyPlant was designed based on a participatory research conducted with five small-scale dairy processors in the Mantaro Valley. They were monitored weekly from May to July 2013 in order to estimate production functions from raw milk to dairy product. Then, two of them were selected, based on their predisposition to adopt innovative incentives, to carry out the support process and to discuss the feasibility to implement payment systems including milk quality components.

Quantitative data were collected such as volume of milk collected per day, dairy product produced, price of dairy products, cost of processing dairy products, as well as qualitative ones, such as ways of

selecting processed products and paying farmers. These data were used both to design a software structure able to cope with a variety of dairy cases, and to construct a base scenario as close as possible to each given case. The base 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 and/or if a lack of consistency was detected.

Once a satisfactory representation of the manufactured process was achieved, the construction of alternatives scenarios jointly with the processor began. Building alternatives scenario included modifications in (i) processor' current portfolio towards higher value products; (ii) the volume of milk collected per day and (iii) the payments to his milk suppliers. Outputs from these alternative scenarios were discussed and the support process was evaluated with the processor in a final meeting.

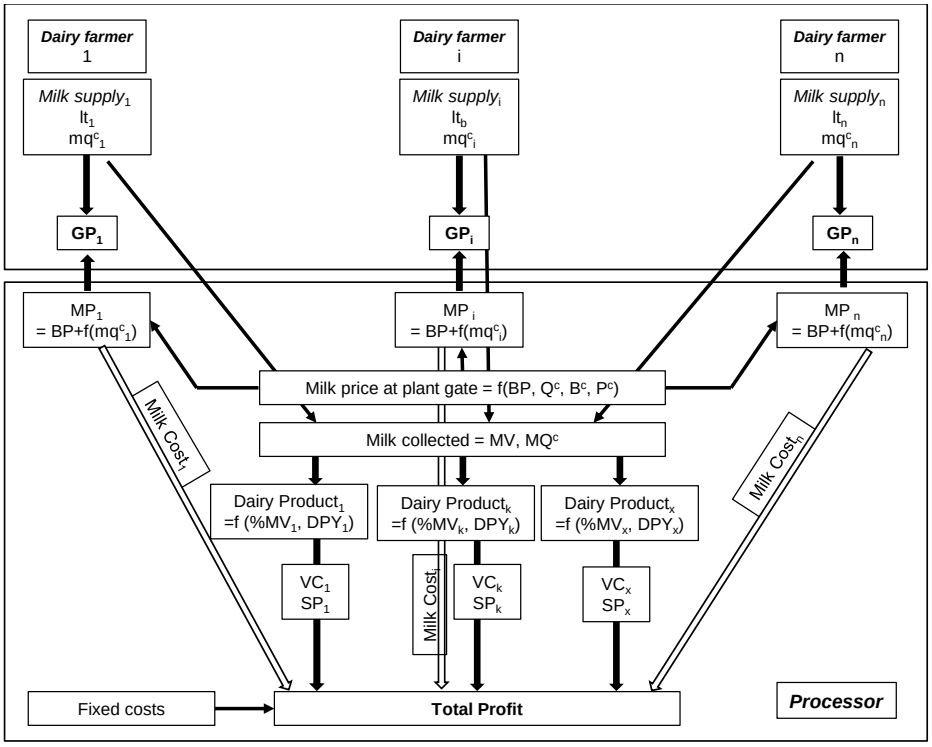
### 4.2. Synthesis of Results

#### *4.2.1. About the simulation tool*

DairyPlant is based on the analysis of the milk supply from farm level to plant gate and the manufacturing process (Figure 11). DairyPlant was designed considering the volume of milk collected per dairy processor in a day. Each milk supplier (an individual farmer, a group of farmers or a private collector) is characterized by (i) milk quantity supplied to the dairy processor in a day; (ii) values of up to three quality components (milk composition or milk hygienic values) from each milk supplier; and (iii) farmers' capacities to increase, decrease or keep their current quality levels if the payment system is changed. This capacity is subjectively assessed by the processor based on the knowledge he has of his suppliers, since there is no direct mathematical relation between the variation of the payment system and the modification of milk quality supplied by each farmer.

Processing analysis take values of total raw milk collected and quality components evaluated from the supply analysis to calculate the outputs of the dairy manufacturing process. The proportion of milk used in the production of each dairy product is selected by the software user according to the product portfolio selected for a given scenario. The list of product manufactured allows the introduction of

intermediate products in the analysis e.g. cream for butter or whey for ricotta cheese. The yield of each dairy product, i.e. the quantity of milk or intermediate product required to produce 1 kg of dairy product, is also defined by the software user based on existent formulas or in-situ controlled experiments. Processing costs are split into milk collection, product-related processing, packaging and marketing costs. Each fixed cost is also defined and split between processed products according to each processor's choice. At the end of the simulation, processors obtain the total profits related to a given dairy portfolio. Up to 10 marketed dairy products and 10 intermediate processed products can be included in scenarios.




**Farmer's variables**
lt$_i$= Liters of milk delivered by farmer *i*
c = Milk quality component
mq$^c_i$ = Value of milk quality component *c* for farmer *i*
GP$_i$ = Gross product of farmer *i*

**Processor's variables**
BP = Base milk price per liter of milk
Q$^c$ = Base value for quality component *c*
B$^c$ = Bonus value for +1% of quality component *c*
P$^c$ = Penalty value for -1% of quality component *c*
MP$_i$ = Milk price paid to farmer *i* for his milk quality
MV = Total milk volume collected
MQ$^c$= Average value of quality component *c* for MV
%MV$_k$= Proportion of MV dedicated to Dairy Product *k*
DPY$_k$= Process yield for Dairy Product *k*
VC$_k$ = Variable costs for Dairy Product *k*
SP $_k$ = Sale price of Dairy Product *k*

**Figure 11:** DairyPlant processing model showing milk supply and transformation processes

DairyPlant also allows the design of milk payment systems. It includes a milk base price plus a combination of up to three quality variables, either chemical or hygienic, assuming that these variables are actually measured at the plant gate and so defined for each supplier. For each variable the user gives the base value and a penalty and/or bonus for each point respectively above or below the base value. So, simulations may include payment systems with (i) only bonuses and no penalties; (ii) both;

or (iii) a fixed base price or a base price + bonus. The calculation of milk cost for the processor and of gross product for the suppliers can then be carried out according to the quality supplied by each one to the plant. DairyPlant was developed using Microsoft Excel 2010, in a user-friendly way in order to facilitate its manipulation and understanding by the stakeholders involved in the support process. The structure of DairyPlant consists in three modules (Table 13) as follows:

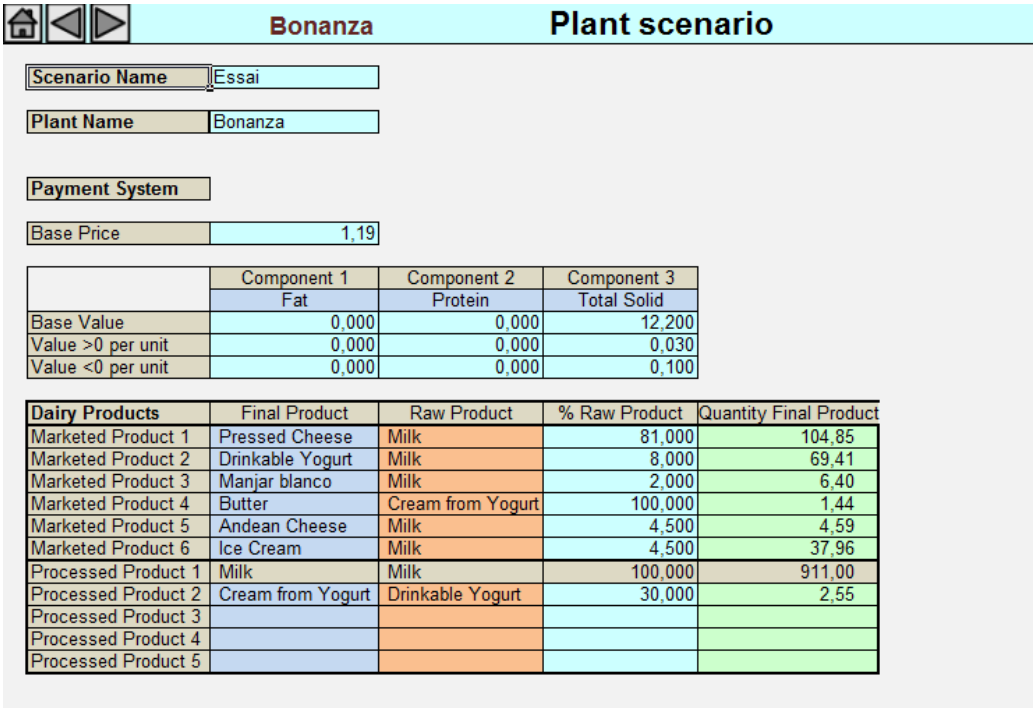
**Table 13**: **Commented list of the variables included in DairyPlant**

| Tool module | Variable name | Comments |
|---|---|---|
| **Parameters**[1] | Dairy Product | List of the processed products encountered in the area |
| | Quality component | List of the milk quality components likely to be included in the payment system (ex: Fat) |
| | Quality improvement | List of farmers' expected reaction if a payment system is implemented |
| | Variable Cost Milk | List of costs related to manufacture of dairy products (ex: Rennet, lactic culture, milk powder, etc.) |
| | Variable Cost Process Product | List of costs related to marketing of dairy products (ex: package, label, etc.) |
| | Fixed Cost | List of costs which are independent from the quantity of milk collected |
| | Process Yield | List of dairy products, yield values and raw products used in the manufacture of these dairy products |
| **Input variables**[2] | ***Plan scenario*** | |
| | Plant name | Appears on every sheet |
| | Scenario name | Appears on every sheet |
| | Payment System | Base price per liter of milk and the bonus and/or penalties for up to 3 milk quality components. |
| | Dairy Products | Selection of marketed dairy products and intermediate processed products manufactured. Percentage of milk quantities for each one. |
| | ***Supply*** | |
| | Farmers' name | Possibility to introduce up to 100 dairy farmers with their respective liters of milk delivered per day. |
| | Quality component | Data is introduced per farmer or from the bulk tank |
| | Quality improvement | Used to simulate scenarios with hypothetical milk quality variations. |
| | ***Plant fixed costs*** | Selection and distribution of fixed costs between all dairy products manufactured. |
| | ***Marketed products*** | |
| | Product name | Similar for the 10 excel sheets |
| | Sale price per unit | Appears on every sheet |
| | Milk cost | Price according to current processors' sales |
| | Variable processing costs | Based on the total amount of dairy product manufactured |
| | Variable marketing costs | Selection of manufacturing costs for the specific dairy product |
| | Fixed costs of the product | Selection of marketing costs for the specific dairy product<br>Completed automatically from "Plant fixed costs" data |
| **Output variables**[3] | ***Plant results*** | Summary of "Plant scenario" data plus production yield, total quantity produced, gross product, total cost, total profit and profit per unit of each one of the dairy products marketed |
| | ***Farmer results*** | Summary of "supply" data plus milk price, premiums and penalties, and gross product of each dairy farmer. |

[1] Variables which take the same values for a group of plants
[2] Variables which take a value specific of the plant supported and the scenario simulated
[3] Variables which take a value calculated from Input and Parameter variables

Parameters (variables which take the same value for a group of plants), input variables (specific to one given plant: range of dairy products, milk quantity and quality per famer, payment system, costs and gross product per dairy product) and the results (calculated variables for the given case: plant profit and farmers' gross products). Each scenario is run for one day considered as representative of the plant business throughout the year.

Parameters module includes variables required in the "input" module for characterizing a given scenario. The user also defines the raw material used and the quantity of raw material required to produce one kg. of a given processed product. These processing yields are essential to determine the amount of dairy products produced by a processor, based on both the collected milk quantity dedicated to each dairy product and its average quality of all the daily deliveries. The "input" module is divided into four sub-modules: Plant scenario (1 sheet), Supply (1 sheet), Fixed costs (1 sheet) and marketed products (10 identical sheets, one per product). In the "Plant Scenario" the user enters a base price, and optionally a base value (%) for up to three milk components and the economic value of each point respectively higher (bonus) or lower (penalty) than the base value (Figure 12). The "supply" sheet regroups information regarding suppliers' daily milk delivery. For each of them, the user enters his daily volume and the milk quality values for the 3 components selected in the "Plant Scenario" sheet. The total volume of milk collected in a day and the weighted average values of milk quality composition are then calculated for the plant. Quality improvement is qualitatively defined by the processor based on his knowledge about his suppliers' behavior regarding milk quality management. In the "Fixed costs" sheet are entered all the costs which are independent from the quantity of milk collected per day. Finally, each of the 10 "marketed product" sheet represents the daily processing of one dairy product. Once the scenario is characterized, DairyPlant simulates the corresponding milk processing of the dairy plant. Results are presented in two separated sheets called "Plant results" and "Farmer results" respectively, based on (i); the total production costs (fixed and variable) linked to the dairy plant operation; the adjusted milk price corresponding to each farmer after bonuses and penalties and his gross product according to his quantity of delivered milk. This gross product corresponds to the milk cost for the processor.



Bonanza — Plant scenario

| | |
|---|---|
| Scenario Name | Essai |
| Plant Name | Bonanza |
| Payment System | |
| Base Price | 1,19 |

| | Component 1 Fat | Component 2 Protein | Component 3 Total Solid |
|---|---|---|---|
| Base Value | 0,000 | 0,000 | 12,200 |
| Value >0 per unit | 0,000 | 0,000 | 0,030 |
| Value <0 per unit | 0,000 | 0,000 | 0,100 |

| Dairy Products | Final Product | Raw Product | % Raw Product | Quantity Final Product |
|---|---|---|---|---|
| Marketed Product 1 | Pressed Cheese | Milk | 81,000 | 104,85 |
| Marketed Product 2 | Drinkable Yogurt | Milk | 8,000 | 69,41 |
| Marketed Product 3 | Manjar blanco | Milk | 2,000 | 6,40 |
| Marketed Product 4 | Butter | Cream from Yogurt | 100,000 | 1,44 |
| Marketed Product 5 | Andean Cheese | Milk | 4,500 | 4,59 |
| Marketed Product 6 | Ice Cream | Milk | 4,500 | 37,96 |
| Processed Product 1 | Milk | Milk | 100,000 | 911,00 |
| Processed Product 2 | Cream from Yogurt | Drinkable Yogurt | 30,000 | 2,55 |
| Processed Product 3 | | | | |
| Processed Product 4 | | | | |
| Processed Product 5 | | | | |

**Figure 12:** “Plant scenario” sheet

*4.2.2. Supporting small-scale dairy plants in selecting market orientations and milk payment systems*

As it was observed in the previous chapters, small-scale processors at Mantaro Valley face problems collecting uniform milk volumes through the year due to high competition for milk supply. Dairies’ capacity to deal with these constraints is limited, since they do not have sufficient information for selecting the most beneficial resource mix or for designing different milk payment systems. DairyPlant was tested with two small-scale dairy plants (DP1 and DP2) to show them potential benefits they could expect from modifying their current portfolio or from adopting a payment system based on milk quality. Moreover, this approach attempted to develop a prospective thinking about milk quality on small-scale dairy processors, since they currently neglect the importance of rewarding their milk suppliers and managing milk quality on their manufacturing process. Scenarios were configured and the whole set, including the reference set, was simulated for each processor.

*4.2.2.1. Product portfolio*

Fresh cheese is the main manufactured product of Peruvian dairies. It represents between 70 -80% of the milk processed, but it does not necessarily provide the highest profits. Varios scenarios based on

the different distribution of raw milk at plant gate were evaluated; since both small-scale dairy processors were interested in analyze the possibility to process dairy products with higher market value. The scenarios varied according to the amount of milk processors were able to reduce from fresh cheese towards other dairy products and the total profit expected at the end. Results showed that both small-scale dairy processors can have better returns if they diversify their product portfolio (Table 14). DP1 profits may increase by 65% after reducing 45% the milk used to produce fresh cheese by producing more aged cheeses, yogurt and manjarblanco (a product based on the reduction of milk and sugar). DP2 obtained 60% more profits by replacing 20% of the milk from fresh cheese to produce aged cheese. The two dairy processors also suggested the simulation of processing more milk volume in order to do not affect their level of fresh cheese manufactured. DP1 increased their profits in 45% and DP2 in almost 100% if they collect one third more of milk. Nevertheless, competition for milk supply in the area would make this second alternative difficult to implement.

**Table 14:** Simulation of the variation of product portfolio and milk volume collected from two small-scale dairy processors at Mantaro Valley

| | | Dairy processor 1 (DP1) | | | Dairy processor 2 (DP2) | | |
|---|---|---|---|---|---|---|---|
| **Variable** | | Reference scenario | Scenario 1 | Scenario 2 | Reference scenario | Scenario 1 | Scenario 2 |
| Milk collected (liters/day) | | 950 | 950 | 1300 | 450 | 450 | 600 |
| Distribution of raw milk at plant gate (%) | Fresh cheese | **81** | 45.5 | 81 | **70** | 57.7 | 70 |
| | Yogurt | 8 | **25** | 8 | 26.5 | 26.5 | 26.5 |
| | Manjarblanco | 2 | **15** | 2 | 0 | 0 | 0 |
| | Aged cheese | 4.5 | **10** | 4.5 | 2.5 | **15** | 2.5 |
| | Ice cream | 4.5 | 4.5 | 4.5 | 1 | 1 | 1 |
| **Total profit / day ($)** | | 340.7 | 561.5 | 491.5 | 51.1 | 80.0 | 99.3 |

Bold values represent the distribution of raw milk from fresh cheese to the rest of dairy products

*4.2.2.2. Simulation of quality-based payment systems*

Based on the evaluation of milk chemical composition per farmer and on a 11.6% total solids baseline defined jointly with DP1 and DP2, up to 70 percent of dairy farmers receive lower milk prices than they should receive and around 25-30% of them are overpaid. Although the lack of milk chemical quality control seems to be advantageous for dairy processors, this situation is quite risky because under a context of high competition for milk supply they can be left for other processors who offer higher milk prices. A simulation was also conducted to estimate the economic impact of the application a milk

quality payment system on total profits of DP1 and DP2. Simulation of a quality-based payment system considering an increase of 0.3% of total solids after the implementation of a bonus of 0.03 per unit above 11.6% and a penalty of 0.10 per unit below showed differences on dairy processor total profits of less than 5%. The present analysis did not show higher differences in terms of profits mainly because we used as a baseline the percentage of total solids recommended at national level and not the average values in the study area. Indeed, no main effect was observed because the two small-scale dairy processors analyzed receive already milk with higher level of total solids. Nevertheless, the simulation gave to small-scale dairy processors the possibility to better estimate the maximum amount of money they can pay per liter of milk to each of their dairy farmers. Moreover, dairy processors realized that if they apply a quality-based payment system they will be reducing the overpaid farmers, rewarding correctly farmers who provide good quality and ensuring suppliers' loyalty without increasing considerably their milk cost.

### 4.3. Discussion

Although the use of simulation models are essential in dairy industrialized countries to evaluate "ex-ante" potential solutions to given issues such as selecting a milk price or dairy product portfolio and the potential impacts of manufacturing processes on their performances (Geary et al., 2010; Roupas, 2008), there is few literature available regarding simulation tools adapted to small-scale dairy processors or considering milk-quality based payment systems in developing countries. This provide originality to our simulation model DairyPlant, even when it can be seen as a simple dairy processing model compared to the sophisticated predictive models for the dairy industry in developed countries.

However, DairyPlant show two main limitations. Firstly, mechanistic relationships between payment system and farmers' quality changes were not included in the analysis. Indeed, such relationship is difficult to establish in a specific production context, since it is technically uneasy to link feeding or milking practices to a given quality value (Fuentes et al., 2014). However, changing practices needs for the farmer that extra-costs will be compensate by better milk price (Valeeva et al., 2007), which complicates the modeling of such a relationship. Botaro el al. (2013) reported similar constraints regarding changes in milk composition after rewarding dairy producers. (ii) Calculation in the farmer's

results sheet were not related to farmers' profits but to farmers' gross products. The analysis does not include individual farmer's production costs because it would assume that either the dairy processor knows this private information, or farmers agree to give it in a negotiation process with the processor. Since information on individual production costs is a strategic resource both on farm and dairy sides in such a negotiation, it seems unnecessary to integrate it in DairyPlant.

The first trial of DairyPlant received a positive reaction from small-scale dairy processors in the studied case. Indeed, managing milk manufacturing processes and planning milk incentives systems were unknown concepts by stakeholders when this study started. Simulating different scenarios including different dairy portfolios and milk quality payment systems helped small-scale processors to clarify their ideas about these concepts. Most processors realized the need to control milk quality, since it has a direct effect on their performances and economic revenues. Nevertheless, they also stated that stricter controls could push milk suppliers towards processors who are less interested in quality aspects. In such a context, the implementation of simple quality-based payment systems that guarantee win-win scenarios for all the stakeholders could be a key element.

## Chapter 5: General Discussion

### *5.1. Managing milk supply in a smallholder farming context*

Results generated in the present study showed the complexity of the dairy sector in a context such as Mantaro Valley. The co-existence of a large variety of stakeholders, regrouped in formal and informal markets, has an effect on the way the first part of the dairy supply chain is managed and how the different stakeholders participate in the supply chain. First, it allows smallholder farmers and artisanal cheese-makers to be included in the dairy sector without making big investments: avoiding barriers in the form of food safety requirements, grading criteria, bans on side-selling and high rejection rates for not achieving high quality standards (Vorley, 2013). Second, it gives small-scale dairy farmers the choice to avoid formal agreements and change buyers if they are not satisfied with the milk price offered. Third, it increases the competition between formal and informal dairy processors for having a constant milk supply: offering higher milk prices or being less demanding in quality aspects. Fourth, it makes both markets self-regulated according to the free demand-supply of the milk and dairy products. Finally, it forces formal processors to demand high milk quality levels from their milk suppliers in a context where there is a lack of support and incentives from the State but an active participation of informal processors offering better prices to farmers due to their lower production costs and profit structure.

This situation provides more benefits to the informal markets over the formal ones. Nevertheless, trading in an informal environment can also have disadvantages for the stakeholders in the informal sector. Farmers may face problems such as delayed or no payment for volumes delivered, and dairy processors may also be affected when their suppliers, either farmers or collectors, change frequently and deliver poor quality milk, sometimes adulterated, that they cannot control without any formal milk analysis system. It is aggravated by the absence of effective legislation regarding product origin and technical transformation (Aubron, 2007) and the consumption of poor quality dairy products that can be detrimental for urban consumers, since sanitary and health issues are frequently found as critical in these contexts. However, the loose control of the informal sector may be seen as a way for the State

to reduce economic pressure on the dairy stakeholders, to reduce the unemployment rate in the area and to keep pace with rising food demands from the capital.

The limited involvement of dairy processors in terms of contracting farmers or more formal arrangements generates a particular type of interaction between stakeholders where milk supplied is adjusted through verbal arrangements with no incentive for farmers to improve milk quality or processors to support farmers technically. The current situation pushes both farmers and processors to reduce their operational costs, to have much lower entry costs, and to offer milk and dairy products at lower prices. But it limits the implementation of milk quality standards.

Some arguments against contract farming are the unequal benefits obtained by both players, with the producer being the weaker party, and the high costs incurred by negotiation, monitoring and enforcement of contracts with a large number of smallholders (Singh 2002). However, contract farming under the Mantaro context cannot only be considered as an important form of vertical coordination, it also could be seen as a way to increase the competitiveness of the formal sector. Formal processors that are under a contract have lower transaction costs. Benefits of contract farming are skewed toward large producers mainly due to economies of scale in the use of family labor in production and disposal of milk. But at similar scales of production, smallholders derived significant benefits from a reduction in transaction costs due to contract farming (Birthal et al., 2008).

The combination of low investment in training and poor access to land on the small-scale farmers' side, uncertainly in the supply of dairy products through the year on the informal processors' side, and the loose organization at both parts of the supply chain could explain why the relationship between processors, collectors and farmers seems unstable. Fluctuating behavior is observed from many farmers who supply several operators, and from processors who try to convince farmers to supply to them rather than their colleagues. This competitive supplier-client relationship reduces incentives for implementing stricter milk quality controls and improving milk quality, since it means more constraints for farmers who may choose to supply processors or collectors with low quality demands. Nevertheless, to overcome this situation, higher milk prices have to be offered in parallel to the implementation of transparent milk quality payment systems.

*5.2 Determining effective dairy production and collection practices for improving raw milk quality*

Milk quality at Mantaro Valley is often mismanaged in relation to the application of husbandry practices. Although several studies have highlighted the influence of farm management practices on the physico-chemical and microbial composition of raw milk (Elmoslemany et al, 2010; Millogo et al., 2008; Sant'Anna and Da Costa, 2011; Kamieniecki et al., 2004; Sraïri et al., 2005), dairy farmers in the study showed poor application of husbandry practices. Moreover, direct relationships between feeding practices and chemical milk composition were not apparent based on on-farm observations. Botaro et al. (2013) reported similar constraints regarding changes in milk composition after rewarding dairy producers. The transformation of feed into fat and protein remains a complex process, depending on many factors (breed, lactation stage, daily quantity produced) that may overshadow the diet's nutritional effects (Schroeder, 2009). In such a context, the chemical quality appears rather an uncontrolled output than a targeted and managed component of the farmer's business.

Hygienic quality is better correlated to dairy farmer's husbandry practices. However, it was observed that the access to infrastructure and milking equipment did not necessary mean better milk hygienic status. Indeed, gathering cows in a waiting yard, use of a milking parlor or milking by mechanical means were negatively associated with high hygienic values. The poor cleaning regime of these buildings (less than once a day), or a lack of a deep cleaning of milking equipment could explain this result. On the contrary, some hygienic practices such as cleaning barns at least once per day, using a disinfectant to clean the udder before milking, and filtering milk before pouring it in churns demonstrated better effectiveness in improving milk hygienic status. Similarly, values of milk somatic cells showed positive association with low cow dirtiness scores. Moreover, a decreased level of somatic cells was also obtained when the animal house was cleaned at least once per day and when dairy farms had permanent access to a source of potable water.

Application of these practices can have a positive impact on the improvement of milk quality. Nevertheless, problems of lack of bonus for producing high quality milk (Radder et al., 2011), labor constraints, and the lack of training and education limit their application. Indeed, the adoption of husbandry practices is a complex process that depends on the balance between the rewards farmers

can expect, for instance a bonus for delivering good milk quality, and the difficulties and the extra costs they face when implementing such practices. Until recently, it was quite costly to assess milk quality for each farmer, especially when only small quantities are involved. Today, cheaper quality testing devices like ultrasound milk analyzer allow dairy processors to assess quality individually for each farmer, which is a key requirement for traceability, quality management, and incentive pay (Saenger et al., 2013). In that respect, implementation of quality-based payments by processors using new technologies to control milk quality like UMA would be a major innovation to support the sustainable improvement of milk quality. But it requires accurate technical, economic and social evaluation because of its impacts on farmer-processor interactions.

*5.3. Alternatives for the dairy supply chain*

The dairy supply chain at Mantaro Valley has to be reorganized to deal with aspects of milk quality. First, written contracts have to be implemented by the formal sector. They can provide buyers with a greater degree of certainty regarding the availability of supply (Gow et al., 2000), a prospect of higher milk prices (Sauer et al., 2012) and of higher profits to farmers (Miyata et al., 2009). As it was explained, it also increases the competitiveness of the formal sector due to the reduction of the transaction costs. Other benefits associated with contract farming include the access to new markets, technical assistance, specialized inputs, and financial resources. However, it should be inclusive, otherwise if smallholders are mainly excluded from contracts it may serve to exacerbate income and asset inequalities (Key and Runsten, 1999). Second, the establishment of farmers' organizations can be suggested as a way to manage and somehow control the milk supplies of their members who deliver small quantities of milk every day; to reduce logistic costs along the chain (Vijayalakshmi et al., 1995) and to provide services close to farmers' needs (Faysse et al., 2012); to increase farmers' bargaining power (Sauer et al., 2012; Valentinov, 2007); and to facilitate the relationships with dairy processors by limiting the intermediaries between farmers and processors.

Finally, providing support regarding strategic issues such as market orientation and design of payment systems can increase dairy processors' competitiveness. The first attempt of this approach was done with DairyPlant, which allowed the assessment and comparison of various alternatives, the acquisition

of knowledge and constructive discussions held jointly with stakeholders. However, a successful implementation of quality-based payment systems will depend of the application of attractive incentives to discourage unfavorable changes in chemical milk composition and the clear understanding of the rules from all the stakeholders involved (Lejars et al., 2010).

*5.4. Research perspectives*

This research highlighted the potential of small scale dairying for contributing to rural development and improving smallholder livelihoods. By focusing our investigation on relationships between farmers and processors we could identify ways of improving farmers' capacities to react to different constraints at Mantaro Valley. We observed that empowering small-scale farmers is essential to make them more competitive. Nevertheless, more investment in marketing and safe milk production is also needed. The state could also intervene to strength the supply chain; however, first it is necessary to determine: What policies can be implemented by the State to regulate and support the sector in improving its efficiency?

By introducing an innovation in the current supply system we could analyze the impact of the availability of new information regarding milk quality on the relationship between farmers and processors. These changes were carefully managed with both stakeholders to then introduce the idea of implementing renovated milk payment systems. However, we couldn't motivate enough dairy processors to establish milk quality controls or quality payments systems in the study area that could provide us a deeper analysis about the impact of possible changes in milk quality management on the supply chain. This situation will probably change in the future, if the consumer' concern about milk quality increases. In that sense, should be necessary to know : How the dairy supply chain has to adapt itself in order to satisfy new consumers demands in terms of quality?

All the information obtained was useful to better define quality standards to be achieved, to motivate processors to measure milk quality, and to nourish the stakeholders' reflections regarding the design of new payment systems at each supply area level. We supported the co-design process not even by monitoring changes stimulated by these new perspectives, but also by providing information on the

potential economic impacts of alternative payment systems. However, we only could develop this approach with formal processors due to their willingness to improve milk quality. Further study regarding alternatives for a better management of milk quality in the informal sector is necessary to design appropriate interventions that can improve the current quality status of dairy products without affecting the downstream part of dairy supply chain. Hence it would be interesting to establish: How the informal sector should deal with milk quality issues and the pressure of the formality without affecting their revenues?

## Chapter 6: General conclusions

The demand for dairy products in Peru has been growing in the last decades. Mantaro Valley experiences the simultaneous presence of formal and informal supply chains, showing the dynamism of the dairy sector in the area. In the capital, formal processors' dairy products are sold in supermarkets, in some restaurants or in small retailers; whereas informal dairy products can be found in local fairs and shops on the street. In both cases, however, there is still a poor knowledge by most of the consumers about how the quality of dairy products is managed before dairy products arrive to the markets.

Behind the dairy products offered in the capital, limited control of milk quality and the unstable relationship between farmers and dairy processors are common problems for ensuring high quality standards. Indeed, lack of organization and high competition between stakeholders render difficult an adequate milk quality management. This situation is aggravated by the lack of state involvement to avoid the risk of interfering with the constant supply of dairy products to the capital. As a consequence, formal and informal markets are self-regulated according to the free demand and supply of the milk and dairy products. This promotes the active participation of informal processors in the supply chain, since no entry barriers or regulations are applied; but reduce farmers' incentives to supply high standards of milk quality and increases the pressure on formal processors to find effective strategies to compete with the informal sector.

Under this context, milk quality management appears as a transversal component that formal dairy processors also have to deal with in order to satisfy the high demand of their consumers. Moreover, targeting high-valued markets such as urban supermarkets should push them to upgrade milk quality by implementing training and quality control programs, and organizing logistics such as better collection practices.

Improving milk quality depends also on stakeholders' capacity to improve their management skills and on better coordination between them within the whole supply chain. Alternatives to improving milk quality in Mantaro valley may include strategies like (i) supporting the establishment of smallholder

farmers' associations; and (ii) implementing simple quality-based payment systems that guarantee win-win scenarios for all the stakeholders. Although the involvement of the Peruvian State in the dairy sector is limited, local and national public institutions can also help : (i) promoting the involvement of the informal dairy sector in more integrated dairy supply chains, by helping informal producers in the differentiation of their dairy products or the promotion of the artisanal quality of the cheese they produce; (ii) providing incentives to the stakeholders in the formal sector in order to avoid their migration to a parallel sector; and (iii) promoting consumers' concerns regarding food quality and sanitary issues by stressing the importance of buying nutritional and hygienic products. The use of a supporting tool adapted to the dairy production in this area and dedicated to strategic issues such as selecting the best portfolio and the design of alternative payment system, contributed to increase the prospective thinking of dairy processors to increase mid-term profits on one hand, and to encourage dairy farmers to improve their milk quality with the idea to get a better income on the other hand. However, implementation will depend on a constant measurement of milk quality parameters and stakeholders' capacity to innovate and create a transparent payment system in the area.

Despite the fact that the informal dairy sector has a structured supply of dairy products to informal markets, this sector remains sensitive to the State's willingness to apply stricter quality regulations. Moreover, the current lack of involvement of the informal sector in more added value supply chains makes informal processors dependent on general market demand which most of the time means lower prices and profits. Alternatives for this sector need to be better explored in future research in order to integrate them in a more resilient dairy production system.

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# SCIENTIFIC ARTICLES

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# The impacts of differentiated markets on the relationship between dairy processors and smallholder farmers in the Peruvian Andes

E. Fuentes Navarro [a,*], G. Faure [a], E. Cortijo [b], E. De Nys [c], J. Bogue [d], C. Gómez [e], W. Mercado [e], C. Gamboa [e], P.-Y. Le Gal [a]

[a] Cirad, UMR Innovation, 73 Avenue Jean-François Breton, 34398 Montpellier, France
[b] IAMM, 3191 Route de Mende, 34093 Montpellier, France
[c] World Bank, 1818 H Street, Nw., Washington, DC 20433, United States
[d] University College Cork, O'Rahilly Building, Cork City, Ireland
[e] Universidad Nacional Agraria La Molina, Apartado 12-056, Lima, Peru

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ABSTRACT

The structure of dairy supply chains in developing countries often shows a large diversity of organization usually based on smallholder farmers' involvement. This paper investigates how a dual supply chain combining both formal and informal markets with predominantly smallholder farmers impacts farmer–processor interactions at technical and organizational level in a Peruvian Andean valley. The analysis is based on three complementary field studies conducted between 2009 and 2012. Results show a large diversity of supply channels in formal and informal chains. Milk flows are observed between formal and informal processors based on a mix of competition and complementarity depending on the season of the year and the level of consumer demand. Smallholder farmers can change processors frequently according to the milk price and services offered, since no contracts link stakeholders. This organization allows smallholder farmers to be involved in the dairy sector but with low profitability. While the informal sector shows better profits per liter of milk than the formal ones, it remains sensitive to the State's willingness to apply stricter quality regulations.

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## 1. Introduction

Relationships between suppliers and clients within supply chains are frequently conflicting because of stakeholders' interdependency and diverging needs and interests (Dunne, 2007). Indeed, the distribution of value through the channel has potential adversarial effects as each participant attempts to appropriate maximum value for him/herself (Hamel et al., 1989). Close cooperation between supply chain members can help them to effectively match supply and demand to increase overall supply chain profitability (Simatupang and Sridharan, 2002). Agro-food supply chains in developing countries face the same sorts of issues, aggravated by their specific features such as fragmentation of raw material and farmers' limited capacity to meet imposed production volumes and standards (Page and Slater, 2003), variability of batches in terms of quantity and quality (Ruben et al., 2007), and perishability of raw material such as in the dairy sector (Amorim et al., 2013).

In these countries dairy supply chains are characterized by a large diversity of farms, including smallholder farmers who consider milk as a valuable source of income (Holloway et al., 2000; Staal et al., 1997; Thornton and Herrero, 2001). These chains deal with a large diversity of organization, from dairy farmers delivering raw milk directly to consumers (Thorpe et al., 2000) to industrial plants collecting milk through collecting co-operatives (Srairi et al., 2009) or cheese processors collecting by themselves (Brokken and Seyoum, 1990). Smallholder dairy farmers may interact with supply chain collectors in three ways (Bernard et al., 2011): (i) no interaction when milk is used for self-consumption or the milk market is functioning poorly; (ii) through short-range networks such as artisanal dairies, direct consumer sales, or peddling, with or without product processing; (iii) through milk collection chains that supply large and medium-scale dairies with milk collected from numerous small-scale farmers. In the latter case, there is a constant flow of raw materials from farmers to dairies and a financial flow in the opposite way, as well as arrangements between farmers and processors to set milk quality standards (Sumner, 2007).

Understanding interactions between stakeholders along the chain can help those designing better strategies in order to increase their benefits and ensure a constant high quality milk supply. For instance the dairy industry may influence the improvement of milk chain performances by providing technical and financial assistance or monitoring activities (K'Obonyo et al., 2011). However little

* Corresponding author. Tel.: +33 46 7614415; fax: +33 4 67 61 44 15.
*E-mail address:* eduardo.fuentes_navarro@cirad.fr (E. Fuentes Navarro).

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**Table 1**
Respective share of informal and formal trade in various national dairy sectors.

| Group | Countries | % of milk processed by formal sector | References |
|---|---|---|---|
| Informal dominant | Tanzania, Ethiopia, Uganda, Rwanda, Sudan, Kenya, Egypt, Cameroon, Senegal, Turkey, Nicaragua, Lebanon, Bangladesh, India | <30 | Padilla et al., 2004; Rao and Odermatt, 2006; Staal, 2006 |
| Medium | Peru, Costa Rica | 40–60 | Knips, 2006; Rao and Odermatt, 2006; Staal, 2006 |
| Formal dominant | Argentina, Brazil, Mexico, Morocco, Algeria, Tunisia, Albania, Sri Lanka, Thailand | 60 << 100 | Knips, 2006; Padilla et al., 2004; Rao and Odermatt, 2006; Staal, 2006 |
| Only formal | EU, USA | 100 | According to EU and USDA legislation |

information is available about the way small-scale farmer–processor relationships affect the performances of both stakeholders in relation to markets in developing countries. Some studies have evaluated in detail the impacts of vertical coordination processes (Dries et al., 2009) or of implementing contract farming (Gow et al., 2000; Miyata et al., 2009). However, these studies assume that both farmers and processors interact under fixed conditions throughout the year and only aim to maximize their profits. The reality may be more complex, for instance, when dairy production is just a part of farmers' activities or when a diversity of markets co-exists in the same area, with various quality standards and arrangements between farmers and processors.

This article aims to identify the strategies implemented by both farmers and dairy processors at technical and at organizational levels in order to respond to uncertainty in milk supply and milk price offered in the simultaneous presence of formal and informal markets. It is based on empirical surveys conducted in a small Andean area (Mantaro Valley in Peru) which benefits from its proximity to the capital Lima for developing its dairy production. After describing the materials and methods used in these surveys, the diversity encountered at farmer, collector and processor levels is outlined before analyzing how they interact and how their relationships impact on the dynamics of the local dairy sector. Finally, these results are discussed by comparing them with similar situations around the world.

## 2. Material and methods

### 2.1. Context

Formal and informal markets differ in the dairy sector according to criteria such as existence and application of official quality standards, especially sanitary standards, contracts between stakeholders along the supply chain, or public tax charges on transactions. The national balances between both markets vary greatly from one country to another, from mostly 'informal' countries in the developing world to Western countries where the informal sector is almost non-existent (Table 1). In that respect, Peru shows an intermediate situation, where the two markets occupy a similar position in terms of milk quantities processed. The Peruvian dairy sector has been growing for the last 20 years with a regular increase in milk production (Fig. 1). Three main drivers have contributed to this growth: the growing urban demand for dairy products and the national protection of the dairy sector from imports though ceased since 2008 (Aubron, 2007), and the food aid regime, based on the "Programa Nacional de Asistencia Alimentaria" (PRONAA) currently called Qali Warma, which provides milk to school children (Knips, 2006).

These national features are also encountered in the Mantaro Valley (75°18′ longitude West; 11°55′ latitude South; 3200 m above

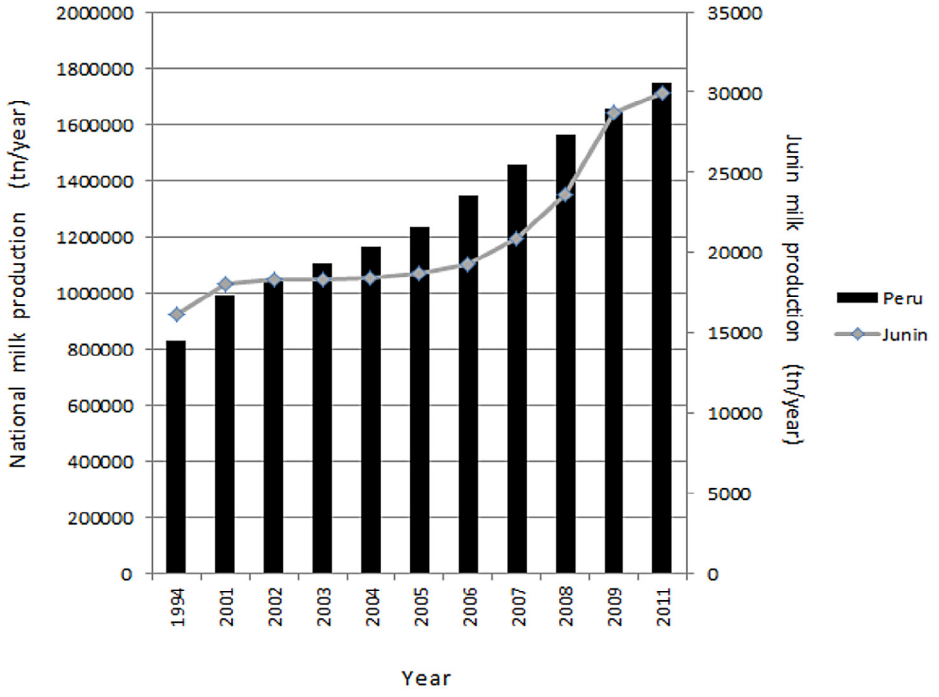



**Fig. 1.** Evolution of dairy production at National level and in the department of Junín (Mantaro Valley) from 1994 to 2011. The figure shows the similar trend in terms of increased volumes over time. (Source: Ministerio de Agricultura del Perú (MINAG), 2014 and Instituto Nacional de Estadística e Informática (INEI), 2010).

sea level) located in the central Andean region of Peru, in the department of Junin. The local annual rainfall varies between 600 and 765 mm per year, but most of the dairy production benefits from irrigated forages such as rye-grass, clover and oats, cultivated on surface irrigation schemes. Dairy production has been important to the area since the 1960s thanks to the development of industrial companies funded both publicly and privately, and to the commercial links with the wholesale market in Lima, the Peruvian capital located 270 km from the Valley. The national land reform program conducted in the early 1970s favored the dismantling of large *haciendas* and the emergence of small-scale farms and co-operatives. Nevertheless, collective co-operatives set up in the area failed to increase agricultural productivity, in comparison with other regions of the country, because of farmer's preference for individualization of land use and ownership (Scurrah and Caravedo, 1991; Trivelli et al., 2006). The terrorism movement active in the area during the 1980s negatively affected the local economy, discouraging producers from investing in farms including those in the dairy sector (Fernandez-Baca and Bajorquez, 1994).

From being the second most important national production area in the 1970s, the Mantaro Valley nowadays provides only 2% of Peruvian dairy production. However, milk production has been increasing since 1994, reflecting much of the dynamic growth found at the national level (Fig. 1). Indeed, the establishment of a collection center belonging to a multinational dairy company in 2005 has provided local dairy farmers access to technical support and credit (Aubron, 2007), and the possibility to increase their milk production by offering a secure outlet for their produce. This dynamic combined with the turbulent history of dairy production in the region has led to a large variety of dairy farmers, involving almost 40% of the local rural population in a rather small area (approximately 3000 $km^2$), and of collecting and processing actors.

### 2.2. Data collection

Data were collected from three complementary studies conducted in the Mantaro Valley between 2009 and 2012. The first study, conducted in 2009, aimed to investigate the degree of involvement of small-scale dairy farms in local dairy supply chains. It was based on surveys mixing collection of quantitative data and stakeholders' interviews, conducted at three levels over 4 months (40 dairy farms, 12 dairy processors, and support institutions). Data related to the characterization of dairy farmers, as well as farming and processing systems were extracted from this analysis. The second study, carried out in 2011, intended to get an overview of the Mantaro dairy sector and to determine how the commercialization system involving small-scale producers operates. For this purpose, 146 farmers from 1327 dairy farms (11% of the total) and 26 dairy processors out of 62 dairy processors (42% of the total) from the province of Concepción were interviewed by means of structured questionnaires. The sample size was calculated using the finite population formula with the information available from the 1994 National Agricultural Census. This study provides key information about differences in markets in which dairy processors are involved.

The third study, conducted in 2012, aimed to understand how farmers', collectors' and processors' relationship affects both milk quantity and quality management. In-depth interviews were conducted with three dairy processors (one large, one medium and one small); the milk collection center belonging to a multinational company; one independent milk collector; one farmer association; and at least five small-scale dairy farmers per processor, from three districts of the Mantaro Valley (Concepción, Matahuasi and Apata). Data regarding interactions between actors along the supply chain, milk quality, milk prices, product quality and current state participation were analyzed from this study. Moreover detailed data regarding costs and gross products were collected from two artisanal cheese-makers and two medium-scale dairies, which accepted to provide this information.

In every study, dairy processing units were purposively sampled in order to represent the largest diversity of cases, based on their volume of milk processed, technological level and their market orientation. Dairy farms were selected either randomly (2011 study) or because of their links with the surveyed processors (2009 and 2012 studies).

### 2.3. Data analysis

A farm typology was designed based on the 2009 farm survey. A structured table was built in Excel 2010 (Microsoft). Descriptive statistical analysis were performed in SPSS for Windows (version 14.02, © 1989–2005). It was combined with a detailed qualitative analysis of each farm in order to understand the consistency between the farmer's objectives, strategy, practices and performances. Following the methodology proposed by Landais (1998) farms were then aggregated qualitatively in homogeneous clusters combining three main criteria of differentiation: activity orientation (dairy specialized versus diversified crop and livestock production), herd stocking density and land availability. Each farm was then assigned by type and each type was characterized by the range of its assigned cases. Using the same process, different types of processors and their channels of commercialization were distinguished. Results of both the 2011 and 2012 studies allowed the completion of cluster descriptions by including interaction characteristics between farmers and processors, and to determine average milk prices and profits at farm and processor levels.

A budget simulation tool was developed with Excel 2010 (Microsoft) in order to compare profits per liter of milk between farm and processor clusters. Calculations were performed for each type of farm/processor cluster by taking into account (i) the kind of market which affects the General Sale Tax (GST) recovery (yes for formal; no for informal), (ii) six farm types according to their targeted market (formal or informal) and their labor structure (one employee or only family labor), (iii) two types of processors (formal and informal, each collecting 700 l/day), (iv) average production costs based on stakeholders' practices, labor costs, the kind of equipment they use, (v) milk prices and (vi) GST rate. Calculations were made for 1 day of activity in two seasons: rainy (December–April) and dry (May–November). The exercise considered average production costs of dairy farmers for each type of farm, based on the 2009 farm survey. Average costs of dairy processors were calculated based on the costs of the two formal and the two informal cases surveyed in 2012. Milk production at farm level was reduced by 20% during dry season to simulate the effect of decreases in forage. Costs and products were reduced to 1 l of milk and per day, according to the farmers' daily production of milk, or the processor's daily production of cheese by using an average cheese yield coefficient based on measurements conducted in three dairy plants. These indicators were chosen to allow a comparison of economic efficiency between the different types of farmers/processors in the area irrespective of their size.

## 3. Results

### 3.1. A diversity of supply channels dealing with two contrasting markets

According to the 2011 survey in the study area, 13 channels of distribution were identified based on the kind of processor, the kind of product marketed and the kind of market involved (Table 2). Dairy

**Table 2**
Description of the 13 supply channels identified at Mantaro Valley (2011 survey).

| Type of processor | Product commercialized | Type of channel | Market | % of total milk produced in the Valley |
|---|---|---|---|---|
| National dairy industries | Evaporated and UHT milk | 1 | Retailers and supermarkets in Lima | 7.3 |
| | | 2 | Local retailers and supermarkets (Huancayo) | 19.9 |
| Formal small and medium scale industries | Pasteurized fresh cheese | 3 | Retailers in Lima | 10.0 |
| | | 4 | Supermarkets in Lima | 8.4 |
| | | 5 | Local retailers (Huancayo) | 0.5 |
| | | 6 | Local supermarkets (Huancayo) | 1.6 |
| Artisanal cheese makers and informal processors | Raw fresh cheese | 7 | Retailers in Lima | 27.6 |
| | | 8 | Local retailers (Huancayo) | 4.1 |
| | | 9 | Local fairs | 1.1 |
| | Fresh milk | 10 | Local retailers (Huancayo) | 2.8 |
| Both (formal and informal processors) | Other dairy products (yogurt, butter, etc.) | 11 | Local retailers (Huancayo) | 8.3 |
| Self-consumption | Fresh milk | 12 | Local community | 3.2 |
| Self-processing | Raw fresh cheese | 13 | Local community | 5.2 |

production is oriented toward three main marketed products: fresh cheese, evaporated and UHT milk and fresh milk. Fresh cheese accounts for 53% of raw milk from the valley after pasteurization or not, while evaporated and UHT milk accounts for 27% and direct consumption of raw milk for 3%. The remaining quantities are used for other dairy products, such as manjarblanco (a product based on the reduction of milk and sugar), yogurt or butter (chain 11). Farmers may consume their own production (chain 12) or sell raw milk directly to local consumers (chain 13).

Processors include two multinational dairy industries, several local medium-scale dairies and artisanal cheese-makers. They differ according to their products, their technology and their market orientation, leading to a large diversity of chains. Any category of processor can choose to sell in Lima or to focus on the valley market, especially its main city Huancayo, which accounts for 117,000 inhabitants (Instituto Nacional de Estadística e Informática (INEI), 2007). Distribution outlets include supermarkets and retailers, which may differ by their specifications regarding the kind of marketed products. Both formal and informal channels are involved in fresh cheese markets. Formal channels (from 1 to 6 in Table 2) consist of supermarkets and retail stores buying from dairies and selling to wealthy urban consumers. These markets demand a constant quality of products and a guaranteed safe product, sometimes based on HACCP hygiene labels. Only formal processors, which are medium-scale companies constituted as dairies and commercialize their products with a sanitary control, can respond to these specifications including milk pasteurization and labels on the products that indicate ingredients, track and trace data and an expiration date. Payment is made in an official way, with receipts and payment of taxes.

Informal channels (from 7 to 10 in Table 2) mean that operators do not follow official regulations to produce standard dairy products and work in an environment without any tax regulation, strict or permanent quality controls and labeling of dairy products. These channels are controlled by medium and large scale cheese-makers that each process up to 5000 l of milk per day. They target consumers with a lower purchasing power, who favor unpasteurized fresh cheese for its price and its taste. This product does not require sophisticated processing.

Although these two main channels follow their own structure, they are interdependent since they have to deal with the same diversity of farmers who supply them with raw milk. This combination of channels and interdependency between stakeholders, both vertical between farmers, processors and retailers, and horizontal between processors, is assumed to impact the farmer–processor relationship and performance of the dairy supply chains in the area.

### 3.2. A large diversity of dairy supply chain stakeholders

#### 3.2.1. Dairy farmers

Smallholder farmers account for around 60% of the dairy farms in the area. They on average cultivate less than 2 ha and own no more than six dairy cattle, including two lactating cows in production. The average production per cow and per farm is 8.6 l/day and 18 l/day respectively. Despite their vast number, these small-scale farmers account only for 30% of the total milk production in the area. Indeed, they have poor access to some services like credit (only 19% have access), concentrate supply (62%) and training (29%). Fifty-one percent of them have limited access to land leading to high stocking density. They cultivate various types of forage associations (oat forage-vetch forage, rye grass-red clover, or alfalfa) and crops (potatoes, corn, carrots, beans, peas and artichokes) in order to increase their returns and simultaneously reduce risks. However, this crop diversity on small cultivated areas leads to difficulties in providing a constant feeding diet to their cows in a green forage-based system. Approximately 68% of farmers have to buy fodder during most of the year to complement their own forage production.

Six farm types were identified in the analysis (Table 3). The size range of specialized farms from large (T1) to medium (T2) and small (T3) shows the value that even small-scale farmers find in dairy production for improving their incomes. However, smaller farms cannot rely only on their own resources to feed their herd. Despite relatively higher purchases of forage and concentrates, partly bought with money from non-agricultural activities, they obtain lower milk yields per cow than T1 or T2 farms, which underlines their difficulty in balancing herd feed requirements and feed supplies (Fig. 2). Consequently T3 smaller-scale farms show lower but still positive profits per cow than T1 and T2 with the current milk price of around $ 0,37 cents/liter (Fig. 3). Diversified farms do not show lower dairy performances for similar size (T5 and T6). Even when milk yields are low and profit are not high, incomes obtained from dairy production are a source of regular cash-flow and reduce economic risks by complementing incomes from crops or other activities.

This diversity leads to a large variability of daily milk quantities supplied per farm, ranging from 5 up to 300 l/day. Although most of the farmers do not deliver more than 100 l/day, they reported preferring to sell their milk independently instead of grouping their supplies because of the lack of reliability between members and problems of mismanagement from the board members in charge of collective associations. Despite these constraints, farmers' associations recently increased in number when the National and

**Table 3**
Characteristics of the six farm types identified from the 2009 survey.[a]

| Main feature | Specialized dairy farms (>60% forage crops) | | | Diversified dairy farms (<60% forage crops) | | |
|---|---|---|---|---|---|---|
| | T1 Large-scale highly productive | T2 Increasing production | T3 Small-scale – high SD | T4 Large-scale | T5 Small-scale moderate SD | T6 Small-scale – high SD |
| Farmer experience | Long dairy experience | Long dairy experience | New dairy farmers supported by projects | Long dairy experience | Mixed | Long dairy experience |
| Land size (ha) | 7–10 | 1–6 | <1 | 3–8 | <1 | 1–2.5 |
| Land ownership | Mostly rented | Rented | Mostly rented | Own land | Own and rented | Own and rented |
| Hired labor | Permanent | Permanent | Seasonal | Seasonal | Seasonal | Seasonal |
| Herd size (LC) | 23 | 3–9 | 3–10 | 3–11 | 1–2 | 2–7 |
| Genetics | Improved | Mixed | Crossbreed | Crossbreed | Crossbreed | Crossbreed |
| Stocking density (TLU/ha) | <5 | <5 | >5 | <5 | <5 | >5 |
| Forage purchase (%) | 0 | 0–40 | 25–35 | 0–30 | 0–80 | 30–75 |
| Concentrate purchase (%) | 45–55 | 10–70 | 30–60 | 10–70 | 0–50 | 0–40 |
| Reproduction | AI | AI | NM | NM | AI | AI |
| Access to credit | Not necessary | For renting land and for crop installation | Not frequent | For crop installation | No access to credit due to lack of funds | No access to credit due to lack of funds |
| Type of processor supplied | Formal | Formal and Informal | Informal | Formal and Informal | Informal | Informal |
| Main constraints | High variation of milk price and concentrate over the year | Lack of land, high cost for renting land | Lack of sufficient forage and low level of milk production | Low level of milk production | Low level of milk production | Lack of permanent forage and low level of milk production |

LC, Lactating cows; SD, herd stocking density; TLU, Tropical Livestock Unit (1 TLU = 1 cattle weighing 250 kg); AI, Artificial insemination; NM, Natural mating.
[a] Main characteristics were analyzed qualitatively to build the six farm types and then completed with quantitative information for each type of farm.

Regional Government decided to support farmers with artificial insemination stations, training and subsidies, provided they were grouped in such organizations.

### *3.2.2. Collectors: a predominant combination of milk collection and cheese making*

Due to the fragmentation of farmers' supply and the absence of associations collecting milk in the area, processors have favored the establishment of intermediaries specialized in milk collection. Milk collectors collect up to 35% of total milk per day, and up to 50% if collectors who process part of the milk are included. They can work for a processor by (i) collecting milk from farmers that have a prior arrangement with the dairy plant and receiving a fixed payment for the transportation of the milk from farm to plant gate; or (ii) collecting milk themselves and selling it at a given price per liter. Seventy-nine percent of the collectors prefer this second alternative, using part of the milk collected every day to produce fresh cheeses and selling the rest of the milk to other collectors or processors. This balance varies according to cheese demand in Lima. For instance, according to cheese makers, cheese demand increases in January and between May and August because consumers benefit from salary bonuses (respectively at Christmas and on Peru's National day) (Fig. 4). Then, collectors process more milk on their own. However, they sell all the milk to an industry collection center when it decreases e.g. from February to April. Consequently collection centers may expect some irregularities in the milk quantities supplied by a given collector during the year.

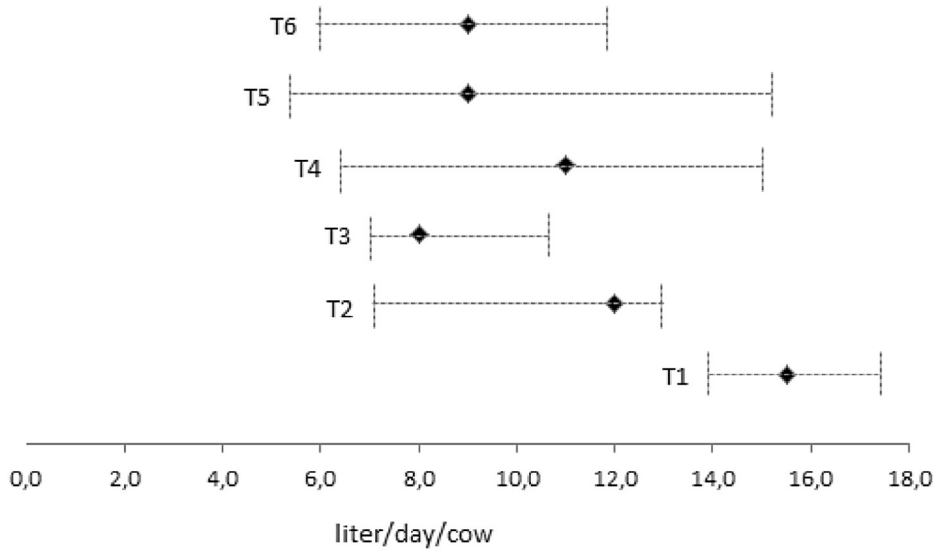



**Fig. 2.** Daily milk yield per farm type (2009 survey). The line shows the minimum, the maximum observed and the average value per each type (n = 40).

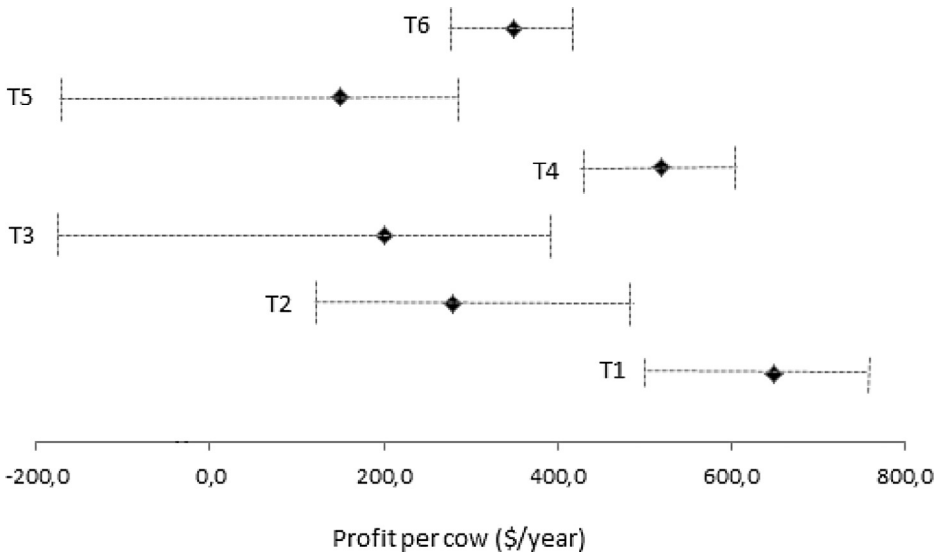



**Fig. 3.** Yearly profit per cow per farm type (2009 survey). The line shows the minimum, the maximum observed and the average value per each type (n = 40).

Collectors' milk collection varies between 400 and 5000 l per day. These large quantities can be obtained by prospecting production areas far from dairy industries' own supplies (approximately 30 km). Milk is bought from farmers who cannot find enough buyers due to their remote location. To recover part of transportation costs farmers are paid 10–20% less per liter of milk than the average price in the area. This system provides a good source of income to collectors based on a small profit per liter assuming a permanent collection volume above 1000 l per day.

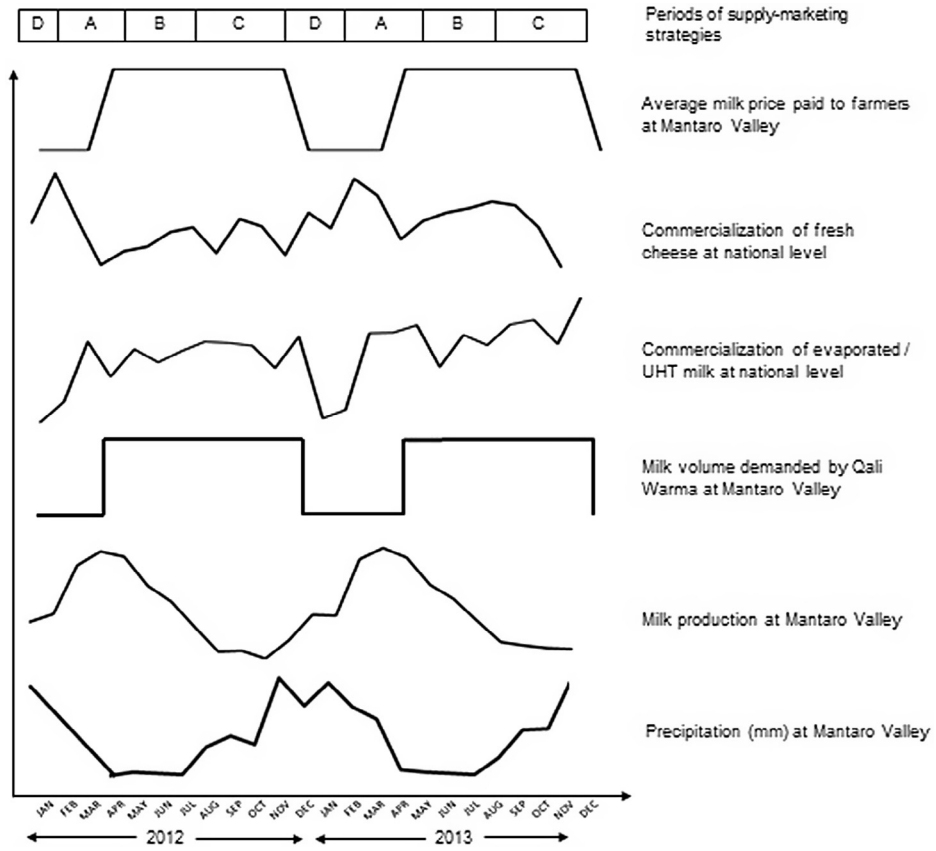



**Fig. 4.** Processors' strategies according to the period of a year, considering average level of dairy products commercialized at national level and milk price, milk production in the area and seasonal effect (precipitation) at Mantaro Valley. Monthly curve variations are based on real data (Ministerio de Agricultura del Perú (MINAG), 2014; Servicio Nacional de Meteorología e Hidrología del Perú (SENAMHI), 2014). Y-axis scales are specific to each variable and not mentioned on the figure. (A) Complementarity between processors during rainy season; (B) competition during dry season; (C) fluctuation in commercialization of dairy products due to low level of milk production; (D) competition at the beginning of the rainy season.

### 3.2.3. Dairy processors

The three main processor types identified, i.e. two multinational dairy industries, several local medium-scale dairies and artisanal cheese-makers, process respectively 44%, 27% and 29% of the total milk commercialized in the Valley. Two multinational dairy companies have installed a collection center in the study area. They receive milk from farmers or collectors at the center gate, storing it in cooling tanks for a couple of days until they have sufficient milk to be sent to Lima for processing. They accept as much milk as they can obtain. About 15 small and medium scale dairies collect from 50 up to 3500 l of milk per day and belong to formal companies. They produce mainly fresh cheeses and yogurt. However, around half of them produce a wide diversity of dairy products such as pasteurized milk, diversified cheeses, butter, manjarblanco and ice cream. Only about two or three of these companies have been integrated in Qali Warma. When the Program is inactive during school holidays (from January to March), its suppliers have to find other market opportunities. About 50 artisanal cheese makers process from 55 up to 5000 l of milk per day. Despite these big volumes, all of them are informal. They buy milk and produce their dairy products, mainly fresh cheese, without pasteurizing the milk before processing it. Artisanal cheese makers use cheese molds made of reed. These molds are difficult to clean but they give characteristic marks to fresh cheeses that are easily recognized by consumers in Lima's markets.

Data collected from the two medium-scale dairies and the two artisanal cheese-makers show that dairies' total production costs per liter of milk exceed artisanal cheese-makers' ones by 25% (Table 4). Indeed, the latter take advantage from the lack of traceability and the poor demand of quality controls in the dairy supply chain. They do not label and do not refrigerate their dairy products, which are reflected in a minimum packaging and electricity costs. They also have lower transportation costs since they collect raw milk with their own mini trucks, and send their products to Lima in shared trucks that normally provide fruits and vegetables to the capital. Formal dairies' costs also increase because of higher asset depreciation and higher staff costs for similar volumes of milk collected. Gross products per liter of milk, which depend on the cheese yield and the cheese sale price, are almost similar since dairies have a better sale price (pressed rather than fresh cheese) but a lower cheese yield. Consequently, the two artisanal cheese makers show higher profits per liter of milk and per day than the dairies' ones.

**Table 4**
Comparison of four processors' costs and profits according to their type.

| Total volume collected | Informal artisanal cheese-makers | | Formal medium-scale dairies | |
|---|---|---|---|---|
| | A1[a] 663 | A2[b] 585 | D1[c] 440 | D2[d] 738 |
| Variable costs ($/l milk) | | | | |
| Milk | 0.463 | 0.426 | 0.437 | 0.441 |
| Mineral salts, rennet | 0.014 | 0.013 | 0.020 | 0.011 |
| Packaging | 0.000 | 0.000 | 0.010 | 0.027 |
| Total | 0.477 | 0.439 | 0.457 | 0.479 |
| Fixed costs ($/l milk) | | | | |
| Staff | 0.009 | 0.016 | 0.044 | 0.051 |
| Water and electricity | 0.002 | 0.002 | 0.034 | 0.025 |
| Transportation | 0.016 | 0.043 | 0.082 | 0.047 |
| Equipment depreciation and maintenance | 0.004 | 0.004 | 0.018 | 0.037 |
| Total | 0.031 | 0.065 | 0.178 | 0.160 |
| Total costs | | | | |
| $/l milk | 0.508 | 0.504 | 0.635 | 0.639 |
| $/day | 337 | 295 | 279 | 471 |
| Total gross product | | | | |
| $/l milk | 0.664 | 0.687 | 0.670 | 0.767 |
| $/day | 440 | 402 | 294 | 565 |
| Total profit | | | | |
| $/l milk | 0.156 | 0.183 | 0.035 | 0.128 |
| $/day | 103 | 107 | 15 | 94 |

[a] 5.02 l of milk at 11.4% TS are required for producing 1 kg of fresh cheese sold $3.30.
[b] 4.85 l of milk at 11.6% TS are required for producing 1 kg of fresh cheese sold $3.30.
[c] 8.29 l of milk at 11.6% TS are required for producing 1 kg of pressed cheese sold $5.50.
[d] 7.25 l of milk at 12.2% TS are required for producing 1 kg of pressed cheese sold $5.50.

The distribution of the total milk quantity collected between the three types of processors varies throughout the year, according to the season (Fig. 4), the quantity of milk they are able to collect and the market demands. In the rainy season, milk production is high in the Valley due to good forage production in terms of quantity and quality. At the beginning of the season, processors compete for collecting the most amount of milk they can according to their capacities in order to compensate the lower amount of dairy products produced during the dry season (beginning of period D; Fig. 4). When medium-scale processors have reached their process capacity, the two multinational dairy companies are able to collect more milk by themselves or through collectors (end of the period D; Fig. 4). They use these extra quantities to produce evaporated and UHT milk (Period A; Fig. 4). This flexibility and complementarity between processors and the two multinational companies provide the security that dairy farmers require to sell their milk at a reasonable price, even in times of high production. It also reduces the risk of milk spoilage at farm level if milk production exceeds the processing capacity of local cheese makers. In addition, it provides an answer to the perishable feature of raw milk when the cold chain is broken, as is often the case in the Mantaro Valley. In the dry season, when milk production is lower, local processors compete to collect enough volume and offer higher prices per liter of milk than the two multinational dairy companies (Periods B and C; Fig. 4). This higher monthly variation of milk production compared to dairy product consumption explains why milk price paid to farmers in Mantaro Valley is more related to the variability of milk supply in the area than of urban demand. Moreover, the dynamic of milk distribution between processors allows the local production to be aligned with the variability of the demand for dairy products in Lima throughout the year, amplified locally by specific actors like Qali Warma during school periods.

### 3.3. Current relationship between dairy farmers and processors and their effects on the milk supply

Farmers and processors interact closely to a "spot market" system, even when large quantities of milk are exchanged. Payment is usually done every weekend and by cash, since farmers do not have any type of contracts with their milk collectors or processors. Dairies which sell to the Qali Warma national program are an exception to this pattern. Qali Warma pays attractive prices to processors but requires them to have written contracts with farmers and to reach high quality standards which could exclude small-scale milk producers from this remunerative marketing channel. Although processors delivering milk to Qali Warma pay 15–20% higher price per liter of milk when the program operates from April to December, there is a constant risk that farmers will choose to break the contract and sell to parallel spot markets if the latter price rises above the contract price.

Farmers usually sell their milk to a collector who may retain their loyalty based on a better price, punctual payment, security of milk collection or services furnished. Without any formal arrangement, the trust and reliability between actors is central to securing commercialization and supply regularity on both sides. Indeed, farmers with less than 100 l/day deliver milk to the same collector or processor every day. But medium and large-scale farmers with 100 up

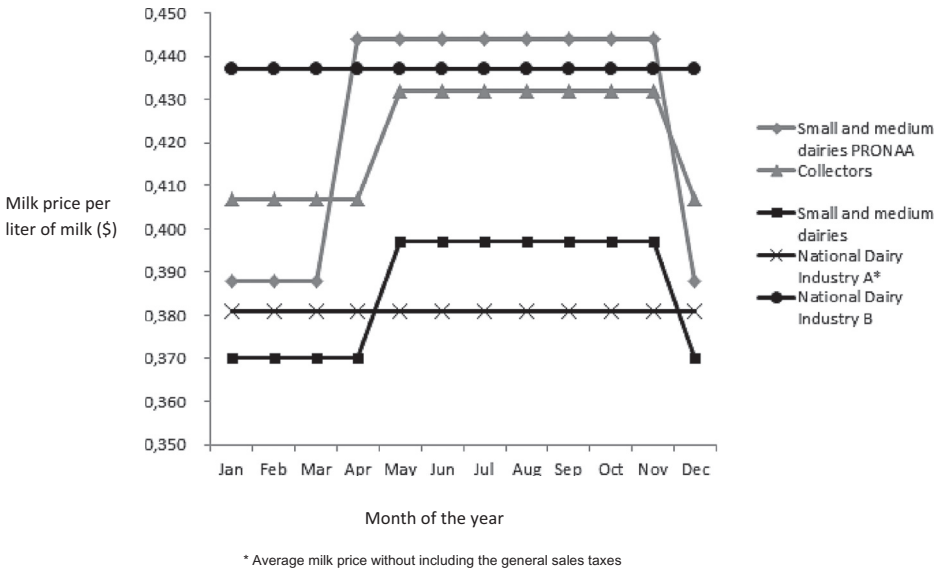



**Fig. 5.** Yearly milk price in 2012 according to type of collector or processor (Concepción district; 2012 survey).

to 500 l/day prefer to deliver milk to several collectors/processors at the same time, in order to reduce the risk of non-collection when the demand decreases or of nonpayment if the collector disappears.

Milk price in the Mantaro Valley varies according to the time of the year and to the kind of processor. Formal processors pay 0.37 $/l in the rainy season and 0.40 $/l in the dry season, while informal ones pay 0.41 $/l and 0.44 $/l respectively (Fig. 5). This price difference reflects the strategy adopted by the informal sector in order to attract dairy farmers following the development of the formal sector in the area. The volume of milk bought at the farm gate and the distance between the farm and dairy also influences the final price. Only one multinational dairy company applies a payment system that includes quality criteria (level of total solids and microbiological content). It also adds the GST in the payment if its suppliers demand it, something scarcely asked for by farmers since most of them are not constituted as companies and prefer to remain informal and unknown by the national tax system.

The limited product specifications laid down between farmers, collectors and processors has led to little regard for milk quality, both physical, chemical and sanitary. Milk density is measured by artisanal cheese makers and medium dairies in order to detect water mixed with milk. Fat and protein contents are never measured despite their impacts on cheese yield. Collection organization is quite loose including plastic containers, long collecting routes with inadequate frequency and the absence of a cold chain. Sanitary quality management practices are quite poor both at farm, collector and processor levels (except for the multinational companies), even when stakeholders have been trained on the subject. Most of the farmers just wash the cow's udder with water before starting the milking process. Collection is performed mixing individual deliveries without keeping a quality record from each farmer. Processors do not follow strict milk quality control procedures during milk delivery at the plants. Nevertheless, collecting poor and irregular quality milk represents a real problem for processors in terms of milk adulteration with water, hygienic conditions of processing and uncertain cheese yields for a given amount of milk collected.

### 3.4. Destination of dairy products

Generally processors prefer to deliver their products to Lima, since it is more attractive in terms of price and volume demanded. However, the local market, Huancayo, is also targeted, even when it may mean lower profits per dairy product, because it reduces transportation costs and the risk of product deterioration. Formal processors' dairy products are refrigerated again when they arrive in Lima, while informal processors try to sell their products as soon as possible. Formal processors' dairy products are sold in supermarkets, in some restaurants or in small retailers. Informal dairy products can be found in local fairs and shops on the street. Processors indicate that consumers in Lima prefer "informal" fresh cheese, viewed as good quality because it is artisanal. They also favor cheese saltiness which is the result of cheese-maker preservation practices. These characteristics, plus a cheaper price per unit, have made the informal cheese market successful in Lima.

In this context, characterized by a mix of competition and complementarity between the formal and informal sectors, depending on the season of the year and the level of consumer demand, both chains impact each other. When the price of unpasteurized fresh cheese is high in Lima, formal processors have to deal with the increased demand for milk from the informal sector (Periods B and C; Fig. 4). They have to compete for milk supply by offering a higher price to their farmers, which results in a reduction in profits. In contrast, informal processors align their processing and marketing practices with consumers' needs and their willingness to pay. But the lack of label or origin differentiation makes these processors sensitive to a decrease in retailers' demand. For example, fresh cheese in "La Parada" informal market (Lima) is sold as "Queso Fresco" irrespective of its geographical origin. This lack of differentiation makes cheese makers from Mantaro Valley vulnerable to reductions both in the price and in the amount of product they sell when there is a surplus of fresh cheese supplied from a different region.

### 3.5. Impact of the type of market supplied on stakeholders' profits

The farm types which provide milk to informal processors (T3, T5 and T6) are not affected by possible changes on individual profits, since they do not sell to formal processors. Contrary to this situation, the individual profits of farm types which may deliver milk to both formal and informal markets (T1, T2 and T4) show differences according to the type of market channel supplied. T1 profit per day is significantly higher than the rest of the types due to the large amount of milk produced. However, T1 has higher milk production costs and, as a consequence, lower profit per liter of milk

**Table 5**
Farmers' production costs, profits per liter and per day ($) when they sell to formal and informal dairy processors, and General Sales Taxes (GST) balance per liter of milk at Mantaro Valley (2012 survey).[a]

| Farmer | Farmers' production cost ($/l) | Formal processor | | Informal processor | | GST balance ($/l) | |
|---|---|---|---|---|---|---|---|
| | | Profit per liter ($) | Profit per day ($) | Profit per liter ($) | Profit per day ($) | Rainy season | Dry season |
| Farmer T1 | 0.328 | 0.030 | 7.111 | 0.086 | 20.711 | 0.014 | 0.020 |
| Farmer T2 | 0.267 | 0.082 | 2.960 | 0.139 | 5.000 | 0.022 | 0.027 |
| Farmer T4 | 0.305 | 0.049 | 2.167 | 0.106 | 4.661 | 0.017 | 0.023 |

GST, General Sales Taxes.
[a] Results obtained using a budget simulation tool developed with Excel 2010, considering average values for each type of farm.

produced compared to T2 and T4. T1 profit per liter is increased almost three times if they sell to informal processors. Compared to T1, T2 and T4 profits can be doubled, even when the differential between profits is in the three cases 0,05 $/l. This result is explained because T2 and T4 have already better profits per liter than T1 when they sell to formal processors (0.082 and 0.049 vs. 0.030 respectively). In any case, the difference with the formal chain corresponds to their positive GST balance (they sell more than they buy). So farmers do not get any advantage from being part of the formal sector (Table 5). Small differences were observed on farmers' profits per day when the seasonality effect was considered. Only for the case of T1 a reduction in milk production was significantly compensated by an increased price during the dry season.

The formal processors' profit decreases to 0.061 $/l when they get milk from farmers who are not interested in paying GST; because in this scenario the formal processors cannot recover the GST through the milk price charged to the consumer (Table 6). Informal processors achieve a better profit per liter of milk than formal ones in any case. Indeed their cost difference with the formal chain (after GST deduction) is only 0.042 $/l while their product difference is 0.078 $/l. Informal cheese-makers value milk at 0.472 $/l compared to 0.514 $/l for formal processors before GST deduction.

So, in the current context of production costs and milk/cheese price structure, the informal chain achieves better profits per liter of milk than the formal one. In a context of competition for milk at farm level, informal processors can then offer better milk prices to farmers, especially during the dry season when milk production is lower. This economic result pushes many stakeholders to remain in the informal sector, especially since GST management demands more administrative work.

### 3.6. State involvement in dairy development programs

In the last decade, only a few government programs have been implemented for increasing small-scale dairy farmers' adoption of new technologies and competitiveness. Programs like AGRO RURAL and PROGALE have shown limited impacts on the improvement of the dairy supply chain, since they were mainly providing subsidies for veterinary products, services or economic capital to farmers but without sufficient technical assistance and monitoring of subsidy utilization. Currently, some local and national public institutions are in charge of supporting small-scale farmers. But due to the lack of funding, they worked in a limited area without sufficient trained staff and were not perceived as relevant by 80% of farmers interviewed in 2012.

This lack of funds leads to a general withdrawal of public institutions from the dairy sector. This context could explain partially why the State tolerates the presence of the informal sector without any type of control. Other reasons could be of a social nature. The informal sector ensures cheap food to low-income people in Lima, and it allows small-scale farmers to integrate themselves into the dairy sector without investments required by the formal regulations. But this withdrawal means also a lack of support and incentives targeting the formal sector and its market channels. As a consequence, both markets are self-regulated according to the free demand–supply of the milk and dairy products. This promotes the active participation of informal processors who can offer better prices to farmers than formal ones due to their production costs and profit structure.

## 4. Discussion

### 4.1. A context where formal and informal markets have a shared role

Dairy production in the Mantaro Valley is dynamic and hosts a large diversity of farmers, including a majority of smallholder ones who seek to earn a livelihood from the dairy sector. But the situation is quite unique compared to other contexts in developing countries, since both formal and informal markets have an active participation in the dairy sector, almost 50% each, and decisions in one market directly affect the other one. More interesting is the fact that both markets also follow the same three drivers: firstly, transactions between farmers and processors are located between the spot market and verbal contract, despite that written contracts can

**Table 6**
Processors' production costs and profits and General Sales Taxes (GST) balance per liter of milk at Mantaro Valley (2012 survey).

| Farmer | Processors' production cost ($/l) | Processors' profit ($/l) | Processors' profit per day ($)[d] | GST balance ($/l) | |
|---|---|---|---|---|---|
| | | | | Rainy season | Dry season |
| Processor F[a] | 0.432 | 0.137 | 95.9 | 0.036 | 0.036 |
| Processor F[b] | 0.514 | 0.061 | 42.7 | 0.078 | 0.078 |
| Processor I[c] | 0.472 | 0.195 | 136.5 | – | – |

GST, General Sales Taxes.
[a] Formal dairy buying milk from a formal farmer. For 8 l of milk at 11.4% TS (total solids) required for producing 1 kg of pressed cheese sold 5.50 $/kg and GST discount on sales and purchases including milk.
[b] Formal dairy buying milk from an informal farmer. For 8 l of milk at 11.4% TS required for producing 1 kg of pressed cheese sold 5.50 $/kg and GST discount excluding milk.
[c] Informal cheese maker. For 5 l of milk at 11.4% TS required for producing 1 kg of fresh cheese sold 3.30 $/kg and no GST discount.
[d] Considering an average milk collection of 700 l/day.

provide buyers with a greater degree of certainty regarding the availability of supply (Gow et al., 2000), a prospect of higher milk prices (Sauer et al., 2012) and of higher yields to farmers (Miyata et al., 2009). Indeed, contract farming offers many benefits, including access to new markets, technical assistance, specialized inputs, and financial resources. However, it should be inclusive, otherwise if smallholders are mainly excluded from contracting it may serve to exacerbate income and asset inequalities (Key and Runsten, 1999).

Secondly, the fragmentation of milk production may lead to the establishment of farmers' organizations as a way to manage and somehow control milk supplies of their members who deliver small quantities of milk every day; to reduce logistic costs along the chain (Vijayalakshmi et al., 1995) and to provide services close to farmers' needs (Faysse et al., 2012); to increase farmers' bargaining power (Sauer et al., 2012; Valentinov, 2007); and to facilitate the relationships with dairy processors by limiting the intermediaries between farmers and processors. Nevertheless, only 16% of farmers from the sample stated that they participated in a farmer's association.

Thirdly, without any formal contract, other types of strategies and incentives are necessary, as was observed in the Mantaro Valley. In this kind of context offering attractive prices to farmers (Mdoe and Wiggins, 1996) or avoiding farm payment delays in order to secure suppliers (Dries et al., 2009; Fałkowski, 2012) may be very effective. However, incentives based on milk quality were not observed with the exception of the multinational companies. Logistic constraints and poor regulation controls explain why milk payment in the Mantaro Valley, as in some other cases (Espinoza-Ortega et al., 2007; Gorton et al., 2006) is mainly based on quantity. Then, the flat price changes from one processor to another according to the supply and demand balance during the year and the competition between them.

### 4.2. Unstable relationship between stakeholders within the chain

Milk production in the Mantaro Valley is based largely on the participation of small-scale farmers, something quite common in Peruvian Andean regions (Aubron, 2007). Although these farmers benefit from good access to markets and to irrigation (Bartl et al., 2009b) and by the large demand for milk in the area, their milk production and dairy incomes remain quite limited, in most cases, due to a low availability of good quality fodder, especially during the dry season, and also by the poor animal genetics (Bartl et al., 2009a). The lack of capital limits their capacity to permanently invest in animals, milking machines, purchase of land, or to adopt new technologies (Solano et al., 2000), which finally impacts on their productivity. Moreover, the imbalance between stocking rate and forage production leads to the permanent purchase of forage, which negatively impacts production costs. Farm management, including attention to health problems, good reproductive indices and long lactating periods can all play a role in improving performance (Novo et al., 2013). However, without the capacity to face these difficulties, improving farmers' profits is mainly linked to their capacity to negotiate better milk prices based on processors' competition for milk.

Indeed, processors have to face high competition between formal and informal ones combined with unstable offer of milk and unstable cheese demand in Lima throughout the year. Their limited involvement in terms of contracting farmers or more formal arrangements is explained by the benefits that stakeholders receive for trading informally. Smallholder farmers feel they can easily find buyers and change when they are not satisfied with the milk price offered, rather than negotiating better conditions with their clients. Similarly, processors prefer to avoid having a contract with a price fixed in advance so they can adjust the price they offer to farmers according to the changing price offered by processors or markets. This situation generates a particular type of interaction between stakeholders where milk supplied is adjusted through verbal arrangements with no incentive for farmers to improve milk quality or processors to support farmers technically. Nevertheless, this situation also helps both farmers and processors to reduce their operational costs, to have much lower entry costs, and to offer milk and dairy products at lower prices.

Collectors also play an important role in the supply chain. They make possible the participation of a larger number of farmers in the Mantaro dairy supply chain. However, this interaction with dairy farmers often hinders the possible direct arrangements between farmers and processors and it usually increases by up to 10% the average price per liter of milk in the area.

This combination of low capitalization on the farmers' side, market uncertainty on the processors' side, and the loose organization at both parts of the supply chain could explain why the relationship between processors, collectors and farmers seems unstable. Fluctuating behavior is observed from many farmers who supply several operators, and from processors who try to convince farmers to supply to them rather than their colleagues. This competitive supplier–client relationship reduces incentives for implementing stricter milk quality controls and improving milk quality, since it means more constraints for farmers who may choose to supply low demanding processors or collectors.

### 4.3. Informal chains: an opportunity or constraint?

The simultaneous presence of formal and informal chains shows the dynamism of the dairy sector in the Mantaro Valley, since it responds to different consumers' demand for dairy products. It allows smallholder farms and artisanal cheese-makers to be included in the dairy sector without making big investments i.e. avoiding barriers in the form of food safety requirements, grading criteria, bans on side-selling and high rejection rates (Vorley, 2013). The important presence of the informal sector in Lima is explained by poor State control and the low economic status of the majority of consumers that remain exceptionally poor by any standard. This situation is aggravated by poor knowledge and the lack of interest expressed by most of the consumers buying dairy products without the added value of pasteurization and packaging. Other factors related to consumers' preferences to buy traditional products are linked to dietary habits and proximity to retail outlets (Francesconi et al., 2010).

The involvement of informal processors in the dairy sector is quite normal in developing countries, such as in Eastern Africa (Brokken and Seyoum, 1990; Moll et al., 2007). Similar to Peru, the informal sector provides dairy products to poor urban areas (Padilla et al., 2004) and small-scale farmers are favored, since they do not have the pressure to adopt control measures, which are costly and they are not usually compensated by a higher milk price (Valeeva et al., 2007). Even in an emerging country such as Argentina, only 17% of dairies have sufficient capacity to pay for a quality assurance system (Farina et al., 2005) and most of the small processors operate in informal, local markets where sanitary standards are not met nor worker social security or sales taxes are paid. They can thus charge lower prices for their products. Consumers may also purchase jointly from formal and informal sectors. In Southern Africa, 80% of poor people report occasional use of supermarkets but they still use local stores or street traders for daily and weekly purchases (Vorley, 2013).

Trading in an informal environment can be risky for farmers who may face problems such as delayed or no payment for volumes delivered and for processors when their suppliers, either farmers or collectors, change frequently, and may deliver poor quality milk, sometimes adulterated, that they cannot control without any formal milk analysis system. The absence of effective legislation regarding product origin and technical transformation also contributes to this current situation (Aubron, 2007). Moreover, the sanitary and

health issues are frequently found as critical in these contexts. Delgado and Maurtua (2003) reported that 97.4% of artisanal fresh cheese evaluated in Lima was found unfit for human consumption due to high microbiological contamination, especially *Escherichia coli* and *Staphylococcus aureus*. These high levels indicate potential contamination of products throughout the chain, from raw materials and processing to distribution.

### 4.4. Policy implications for developing the Peruvian dairy sector

Peruvian government policies regarding the dairy sector have not been constant over the last decades. In the 1980s, the Government controlled wholesale and retail prices and managed import quotas in order to encourage the development of the national dairy sector to replace imports with local milk while keeping low consumer prices for dairy products. Unfortunately, that decision strongly impacted on dairy farmers (Bernet, 1998). In the beginning of the 1990s, the Peruvian Government decided to protect its national market from cheap imports. Similar decisions have been made by other countries such as Morocco and Tunisia, which has led to large investments in the local dairy production and allowed small-scale farmers to be involved in this sector (Sraïri et al., 2013). The tariffs and price band system for dairy product imports was implemented in 1993 and benefited the national dairy sector for many years. However, it was removed to favor trade with the Andean Community of Nations and the United States, and completely abolished in 2008.

Nowadays, the Peruvian government promotes the local dairy sector mainly through developing social feeding programs like Qali Warma. However, it is not currently involved in providing support or any direct subsidy either to the local dairy production (credit or inputs) or to the dairy industry; even when contracts between credit institutions and milk processors have proven to be very cost-effective in the Andes (Bernet et al., 2002). Farmers in the Mantaro Valley usually demand technical and economic support from the Government. However they are not so optimistic about the real involvement of the state in the region (Trivelli et al., 2006). Only a few public organizations are present in the area like Sierra Exportadora and Junin Regional Government, but these play a limited role in promoting innovation and are not sufficient to boost the dairy sector (Ortiz et al., 2013). Consequently, farmers and processors are exclusively dependent on their own profits to invest in their business. This situation could hinder the possible expansion of the sector and increase smallholder farmers' economic vulnerability. The loose control of the informal sector may be seen as a way for the State to reduce economic pressure on the dairy stakeholders, to reduce the unemployment rate in the area and to keep pace with rising food demands from the capital.

Despite this lack of economic support available to farmers and processors, active State intervention in the Andean dairy sector is suggested (Bernet et al., 2001) in order to alleviate poverty in the area (Kristjanson et al., 2007) and to improve the performance of the informal sector while recognizing the risk of exclusion when intervening with new forms of regulations and governance (Vorley, 2013). For instance, local and national public institutions could: (i) support the establishment of farmers' associations, to strengthen the smallholder farmers' bargaining power; (ii) improve service supply such as credit and farming advice to smallholder farmers; (iii) support the informal dairy sector to improve its practices and incomes through differentiation and promotion of its artisanal products; (iv) provide incentives to the stakeholders in the formal sector in order to avoid their migration to the informal one; and (iv) promote consumers' concerns regarding food quality and sanitary issues by stressing the importance of buying nutritional and hygienic products.

## 5. Conclusions

Farmers and processors in the study area use diverse strategies to compensate for the lack of more formal arrangements. Large- and medium-scale farmers achieve the highest profits and could invest more in improving their dairy farms. They deliver the majority of their milk to processors from the formal sector, although their profits could be higher by selling to informal ones. Trust in formal companies and security of milk purchase throughout the year are more important for them than higher prices. However, they may deliver a small part of their milk to informal collectors/processors when they estimate that prices offered by the formal sector are too low.

Small-scale farmers are constrained by the lack of land and forage availability for improving cow productivity and reducing their production costs. These difficulties in securing their production results in an unstable situation, where (i) they probably will take the opportunity to change milk buyer if a collector offers more money or (ii) they will probably decide to quit the dairy sector if they find a job. Developing farmers' associations could enable these farmers to negotiate better milk prices, to have access to communal land or to buy cheaper forage and concentrates in group. For the moment, dairy production provides to these farmers a source of employment and a small portion of the total family income.

A positive consequence of the simultaneous presence of the formal and the informal sectors in the area is the inclusion of smallholders in the dairy sector without making big investments. Nevertheless, this co-existence also provides fragility to the whole sector. Formal processors and informal ones compete for milk supply when the demand for fresh cheese increases in Lima, while formal processors show lower profits per liter of milk. On the other hand, the lack of product differentiation makes informal processors dependent on general market demand which most of the time means lower prices and profits. Under this constrained context, formal and informal processors need to identify possible new opportunities in the dairy sector.

The lack of State control has led to the production of poor sanitary quality dairy products by the informal processors as a result of unhygienic production conditions. However, reducing the activities of the informal sector through implementing public quality regulations could cause some social difficulties since many consumers would not be able to find the products they like at an affordable price. Hence, public interventions at processor level have to be deeply analyzed before implementation. Otherwise, strict regulation in the dairy sector could result in very high entry costs causing formal processors to move outside of the market creating a parallel system.

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REGULAR ARTICLES

# Effects of dairy husbandry practices and farm types on raw milk quality collected by different categories of dairy processors in the Peruvian Andes

**Eduardo Fuentes · Joe Bogue · Carlos Gómez · Jorge Vargas · Pierre-Yves Le Gal**

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**Abstract** In developing countries, milk quality is often mismanaged in relation to husbandry practices, collection logistics, and the production of small batches. This paper investigates how the management of milk quality from farm to dairy processor impacts on both chemical and hygienic indicators, in a context characterized by farm scale diversity, the co-existence of formal and informal markets, and high milk demand. It is based on an analysis of the chemical and hygienic quality of milk samples collected over a 12-month period from 20 farms and three dairy processors. Data from the farmers' husbandry practices and the logistics of milk collection were also collected. A large range of quality profiles and farming practices were observed. This diversity is explained by rainfall and temperature pattern, farm size which affects hygienic quality, and lack of efficient logistics between farms and dairy processors. The findings indicate that in a context of high demand for milk and poor private and public regulations, milk quality is impacted upon by poor stakeholders' management practices.

**Keywords** Farmer · Feeding · Milking · Logistics · Peru

E. Fuentes (✉) · P.-Y. Le Gal
Cirad, UMR Innovation, 73 Avenue Jean-François Breton,
34398 Montpellier, France
e-mail: eleuman@gmail.com

J. Bogue
Department of Food Business and Development, University College Cork, Cork City, Ireland

C. Gómez · J. Vargas
Universidad Nacional Agraria La Molina,
Apartado 12-056, Lima, Peru

## Introduction

The improvement of milk chemical composition may benefit dairy farmers and processors in developing countries, since it could potentially add more value to farmers for every liter of milk produced, while processors would receive higher revenues by increasing the milk yields (Geary et al. 2010). Moreover, control of the hygienic status of raw milk could also address possible lack of sanitary management in these dairy supply chains (Bonfoh et al. 2006). However, the predominance of small-scale farmers and medium size processors complicates the quantitative evaluation of milk quality, which is hardly assessed. Hence, this study aims to determine how farmers' and processors' management processes affect both the chemical and hygienic milk quality in a context characterized by the joint presence of formal and informal markets and by high milk demand. The study was conducted in the Peruvian Andes, where an increased annual milk production of 6.5 % has been observed over the past 10 years (INEI 2010) but where farmers and processors still show little concern for quality norms. After describing the materials and methods used for collecting data, the management of milk quality at farm level is firstly analyzed. Then, the collection practices from farm to dairy processor and their impact on milk quality after farm delivery are reviewed. Finally, these results are discussed to understand the milk quality issues in such a context.

## Material and methods

### Context of the study

The Mantaro Valley (75° 18′ longitude west; 11° 55′ latitude south; 3,200 m above sea level) is located in Peru's central Andean region. The annual precipitation varies from 600 to

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765 mm/year but most dairy production benefits from irrigated forages, such as ray grass and clover. The genetic composition of herds is dominated by Holstein and Brown Swiss breeds and their crosses with the local breed "Criollo." Dairy supply chains in this region involve a wide diversity of farmers and processors. Processors can collect milk by themselves at farm gate, or by buying milk collected by independent collectors. These stakeholders interact in formal and informal chains according to their own regulation, control processes, and type of targeted markets (Fig. 1).

### Sampling selection

Based on a preliminary survey assessing the diversity of processors, a milk collection center belonging to a multinational company, one informal and two formal dairy processors and three independent milk collectors, were purposively sampled. They varied in terms of volume of milk collected, technological level, and market orientation. Twenty dairy farmers were then selected among the suppliers of these milk buyers. The sample farms included 60 % of small-scale farmers (production of 20–50 l/farm/day and 8.5 l/cow/day); 30 % of medium-scale farmers (production of 50–100 l/farm/day and 10.5 l/cow/day); and 10 % of large-scale farmers (production exceeding 100 l/farm/day and 12.0 l/cow/day). The two last categories were pooled for analytical purposes.

### Milk quality analysis

Data were collected over 12 months from April 2012 to March 2013. Average total solids, fat, and protein content of each milk sample were measured with Master Eco® ultrasound milk analyzer (http://www.milkotester.com/data/Master%20Eco.pdf). The analyzer was calibrated every month using reference AOAC methods (Helrich 1990). Somatic cell count (SCC) was obtained with the indirect on-farm test Porta SCC®, which converts results of an enzymatic reaction into an estimated SCC (Rodrigues et al. 2009). Hygienic status, measured with the methylene blue reduction test (MBRT), was performed according to the IDF protocol (IDF 1990).

Bulk milk samples (50 ml) were taken once per month from each of the 20 farmers (Table 1). For each farmer, samples (morning and afternoon) were collected and analyzed from bulk churns at the end of each milking and then pooled to obtain an average daily value. A similar sampling protocol was performed during a period of 1 week every month to the processors' truck and the independent collector of each of the three processors evaluated. A complementary evaluation was performed to one dairy farm per processor to determine milk hygienic deterioration from farm gate to plant gate (Table 1). Along with milk analyses, the farmer's husbandry practices were recorded once a month and compared to a set of recommended management practices based on the literature (Table 2).

Descriptive statistics (average, coefficient of variation, and correlations) for analyzing milk quality composition and its relationship with farmers' practices were carried out from the 12-month dataset. The XLStat™2012.6.01 software (Addinsoft, Paris, France) as an add-on to Microsoft Excel™ 2010 was used for that purpose.

## Results

### Milk quality management at farm level

Results of milk chemical composition were found to be acceptable, compared to the values recommended by Peruvian legislation, with an average of 37 g/kg for fat content, 34 g/kg for protein content, and 119 g/kg for total solids (TS). Eighty-eight percent of milk samples were able to simultaneously fulfill minimum requirements of protein and fat content demanded by formal dairy processors without any significant

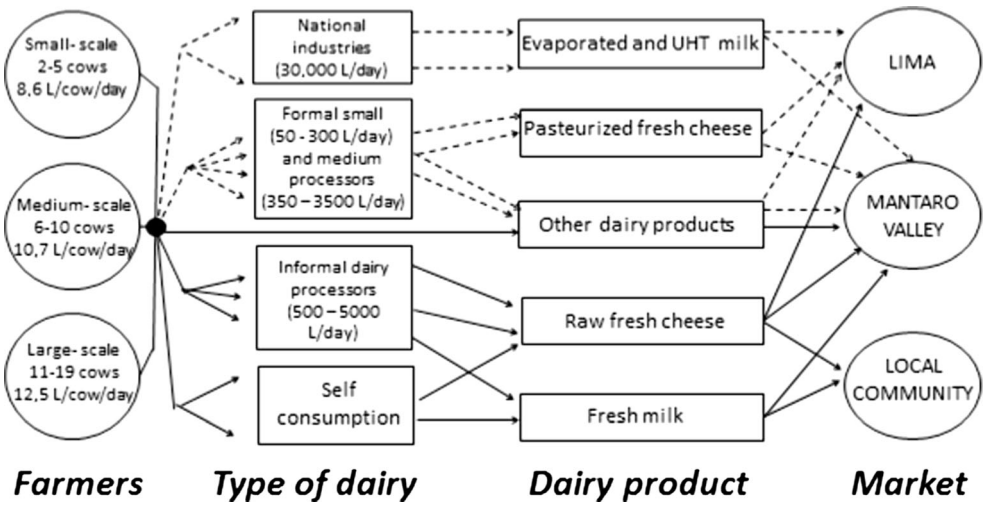



**Fig. 1** Dairy supply channels at Mantaro Valley representing the different types of dairy farmers, dairy companies, dairy products marketed, and type of market targeted. National industries and formal small and medium processors provide products to formal markets (*dotted arrows*), whereas informal dairy processors deliver to informal markets (*plain arrows*)

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**Table 1** Milk sampling process for farmer, processor, and farm to plant gate

| | Number | Sampling frequency | Sampling method | Total samples | Comments |
|---|---|---|---|---|---|
| Farmer | 20 | One day per month per farm | Average of morning and evening sample | 238 | Two farmers stopped milking during the last month |
| Processor | 3 | Each day during 1 week per month per dairy | Sample from own collection+sample from independent collector | 480 | Some weeks' samples were taken only for 6 days |
| Farm to plant gate | 4 farms | One Friday per month per farm | Sampling at three different times: (i) in the afternoon after milking; (ii) the next morning when milk is collected; and (iii) when the milk arrives at plant gate | 144 | Three samples each time |

difference between large-scale and small-scale farms. Ninety-two percent of samples had values of MBRT above the minimum standards (240 min). However, large-scale farmers showed significantly poorer milk hygiene than smallholder ones, with respectively 282 and 342 mean MBRT minutes ($p$ value <0.0001). The average SCC exceeded the upper limit of Peruvian standards, since only one third of milk samples were below 200,000 cells/ml.

Chemical quality variables showed no significant relationship with hygienic quality ones ($r$ values <0.17 for $\alpha$=0.05). But no more than 35 % of milk samples from small-scale farmers and less than 20 % from large-scale farmers had both

**Table 2** List of husbandry practices and their application according to farm size (% of monthly observations during the 12-month monitoring period)

| Practices | Small farm ($n$=154) | Large farm ($n$=84) | Total ($n$=238) |
|---|---|---|---|
| Feeding | | | |
| Regular use of the following: | | | |
| -Home-made concentrate | 10 | 40 | 21 |
| -Mineral salt | 90 | 70 | *83* |
| -Silage | 0 | 30 | 11 |
| -Range pasture | 10 | 0 | 6 |
| -Cereal stover | 20 | 30 | 24 |
| Milking | | | |
| Keep an updated notebook of treatment records | 70 | 70 | *70* |
| Gather the cows in a waiting yard before milking | 0 | 40 | 14 |
| Clean the animal house frequently | 80 | 60 | *73* |
| Use of milking parlor | 30 | 80 | *50* |
| Have a milk-cooling system after milking | 20 | 40 | 27 |
| Udder examined before milking | 30 | 30 | 30 |
| Good cleanliness of milk churns before milking | 100 | 100 | *100* |
| Milking by mechanical means | 0 | 50 | 17 |
| Udder washed before milking | 90 | 90 | *90* |
| The washing water contains disinfectant | 20 | 10 | 16 |
| The udder is dried after washing | 50 | 60 | *54* |
| Frequent training of personnel | 10 | 20 | 14 |
| Predip | 0 | 0 | 0 |
| Forestrip | 20 | 40 | 27 |
| Post-milking teat dipping | 10 | 20 | 14 |
| Use California mastitis test | 0 | 30 | 12 |
| Wear gloves | 0 | 10 | 4 |
| Milk is filtered before depositing in churns | 100 | 100 | *100* |
| Avoid cow restraints during milking | 10 | 10 | 10 |
| Use of potable source of water | 70 | 90 | *77* |
| Average cow dirtiness score | 2.6 | 2.4 | 2.5 |

Italicized values are practices exceeding 50 % of observations

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TS and SCC values above the minimum recommended (Fig. 2). TS and MBRT tend to present a seasonal variation (Fig. 3). During the dry season, when rainfall and temperature are low, TS decreases due to the limited availability of good quality forage, while hygiene improves because of lower bacterial contamination.

Nine husbandry practices out of 26 evaluated were identified as frequently applied, i.e., exceeding half of monthly observations during the 12-month monitoring (Table 2). Feeding practices were mainly based on cut green forage distributed at stable and grazing plots, with an average dry matter intake of 15.9 and 13.6 kg/cow/day for large-scale and small-scale farmers, respectively. Farmers did not calculate diets based on targeted production levels of milk. The amounts distributed were linked to the availability of green forage. Large-scale farmers were more concerned in providing by-product feeds and corn stover than smallholders, which was reflected in higher net energy for lactation provided (23.7 vs. 20.4 Mcal/cow/day on average, respectively). Some milking practices varied according to herd size (Table 2). Large-scale farmers showed more interest in applying practices that demand higher economic investments. Small-scale farmers usually cleaned the animal house more often than large-scale ones, since they milked their cows in the same small space where the animals also rested.

Milk chemical composition was not significantly correlated with feed energy and protein availability in the diet for the overall farm sample. Farms with Brown Swiss cattle show more efficiency in transforming energy into milk fat, while farms with Holstein or crossbreed show a positive link between energy and fat content, but with a large range of variation (Fig. 4). This result highlights the difficulty in establishing clear feeding strategies to achieve higher values of milk chemical components in the feeding conditions prevailing in the study area.

In contrast to expected results, gathering cows in a waiting yard, use of a milking parlor, or milking by mechanical means were negatively correlated with values of MBRT (Table 3). The poor cleaning regime of these buildings (cleaning less than once a day) or a lack of a deep cleaning of milking equipment could explain this result. Values of milk somatic cells showed positive association with low cow dirtiness score. Moreover, a decreased level of SCC was also obtained when the animal house was cleaned at least once per day and when dairy farms had permanent access to a potable source of water.

## From farm to plant gate

Chemical quality was not affected during collection by independent collectors (average milk TS of 119 g/kg at farm level vs. 116 g/kg at plant gate), since processors generally control milk density at plant gate to avoid adulteration. But hygienic quality was considerably reduced, in relation to the way collectors operate (average MBRT value of 324 min at farm level vs. 114 min at plant gate). Indeed, independent collectors use big blue plastic containers because of their larger capacity, and they do not always clean them with detergent. They use a cloth filter on the top of the containers but without replacing it regularly. In order to maximize milk quantities per daily transport, they collect only once per day, they mix milk from several farmers in the same container, and they spend several

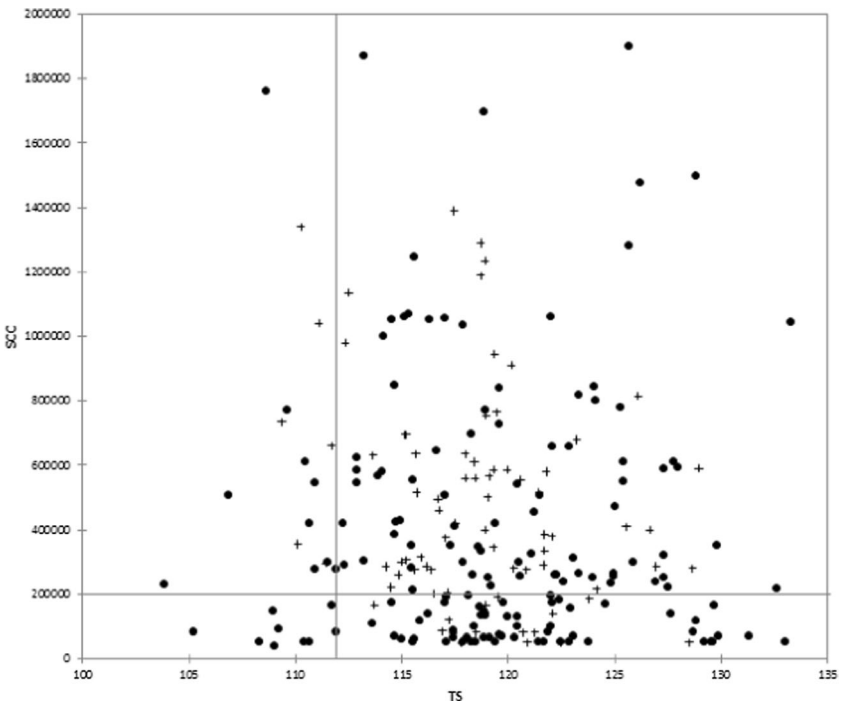



**Fig. 2** Variation of total solids (%) and levels of somatic cell counts (scc/ml) in milk produced at farm level at Mantaro Valley ($n$=238). *Gray lines* indicate minimum recommended value of TS and maximum recommended value of SCC, for Peru's large-scale farmers (*plus sign*) and small-scale farmers (*filled circle*)

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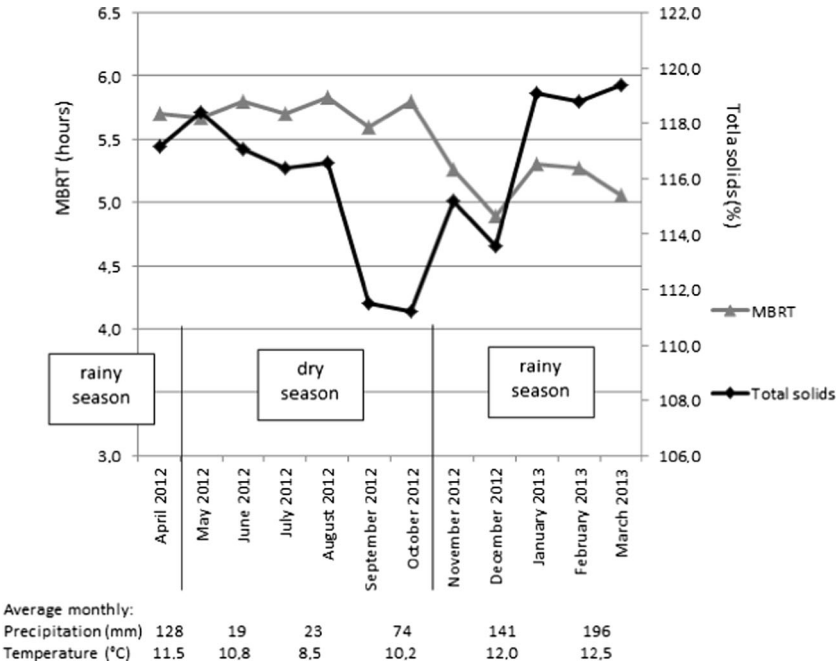



**Fig. 3** Methylene blue reduction test (hours) and total solids at farm level (%). Dry season, no rain and low temperature; rainy season, rainfall and high temperature

hours collecting milk before arriving at the plant gate. These practices reflect the fact that their income depends on the milk quantity they collect each day. Milk chemical quality from processors themselves was similar to the collectors' one (average milk TS of 117 g/kg vs. milk TS of 116 g/kg, respectively). Same result was obtained for the hygienic quality (average MBRT of 132 min vs. MBRT of 114 min, respectively). However, SCC parameter showed the highest variability (coefficient of variation 68 %) and lower SCC levels for milk collected by processors themselves (average SCC of 283,505 cells/ml vs. 425,683 cells/ml, respectively). Indeed, dairy processors had more control of the milk collected, since they dealt with less farmers compared with independent collectors.

In both cases, the absence of a cool chain from farm to plant gate affects hygiene quality, based on MBRT, when milk from

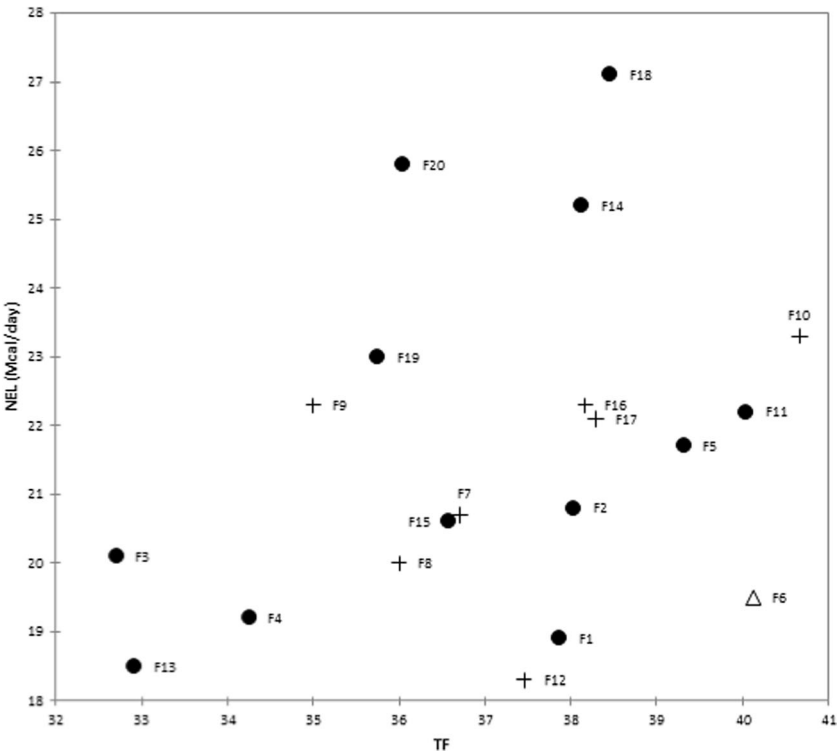



**Fig. 4** Relationship between daily energy supplied by diet and percentage of total fat (g/kg) in the composite milk samples from farms with different breeds. Predominant crossbreed cattle (*plus sign*); Brown Swiss cattle (*white triangle*); Holstein cattle (*filled circle*)) (12-month average per farm)

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**Table 3** Correlations between husbandry practices and hygienic status of raw milk ($n$=238)

| Husbandry practices | MBRT | SCC |
|---|---|---|
| Gather the cows in a waiting yard before milking | **−0.488** | 0.084 |
| Clean animal house | *0.161* | **−0.178** |
| Use of milking parlor | **−0.248** | −0.104 |
| Cows are milked by machine | **−0.387** | −0.022 |
| The washing water contains disinfectant | *0.141* | 0.080 |
| Milk is filtered before depositing in churns | **0.256** | −0.007 |
| Use of a potable source of water for cleaning | −0.052 | **−0.302** |
| Average cow dirtiness score | −0.072 | *0.152* |

Italicized values are significant at $\alpha$=0.05. Bold values are significant at $\alpha$=0.01

afternoon milking is stored at farm gate before being transported to the plant the following morning. Indeed, while fresh milk measured at farm level showed an average MBRT time of 460 min, it decreased to 180 min until it arrives to plant gate, after almost 12-h storage under Mantaro Valley's temperatures (Fig. 5). These results highlighted the importance for both processors and collectors to better manage logistics between farm and plant in order to reduce degradation of milk quality.

The processor's strategy regarding milk quality is mainly related to the target market. The multinational company was the only one that showed real concern for milk quality, through adequate practices at plant gate and during the process (Table 4). Although small- and medium-scale dairies may follow established protocols, they faced constraints such as difficulties with controlling milk temperature at plant gate or lack of containers to collect milk individually from each farmer. Informal processors, who sold products to a less quality-demanding market, did not follow a standard protocol and did not pasteurize milk before processing cheese. They considered pasteurization time-demanding, costly, and leading to lower cheese yields.

## Discussion

### Milk quality at farm gate: farmer's concern or uncontrolled output?

Despite a context where few controls or quality-based payment systems are implemented, farmers were able to achieve the required chemical and hygienic milk quality levels. Milk total solids were usually high, and the hygienic status of raw milk was good compared to other developing contexts where hygienic contamination is a critical issue (Gillah et al. 2014). But SCC showed a large variability and levels above 400,000 cells/ml, indicating the lack of periodical use of tests to prevent mastitis, and the prevalence of clinical and subclinical mastitis in milk (Gargouri et al. 2014) which finally affect farmers' profitability due to increased control costs (Moges et al. 2012).

Climatic conditions partly explained quality variability, as shown by Larsen et al. (2010). But direct relationships between feeding practices and chemical milk composition were not apparent based on on-farm observations. The transformation of feed into fat and protein remains a complex process, depending on many factors (breed, lactation stage, daily milk production) that may overshadow the diet nutritional effects (Schroeder 2009). Breed selection has probably more of an impact but it is a long and costly process. Milking practices would have a bigger impact on hygienic quality. Although well trained on these issues, large-scale farmers showed poorer hygiene results due to a lack of labor investment. Moreover, without a bonus for producing hygienic milk, they

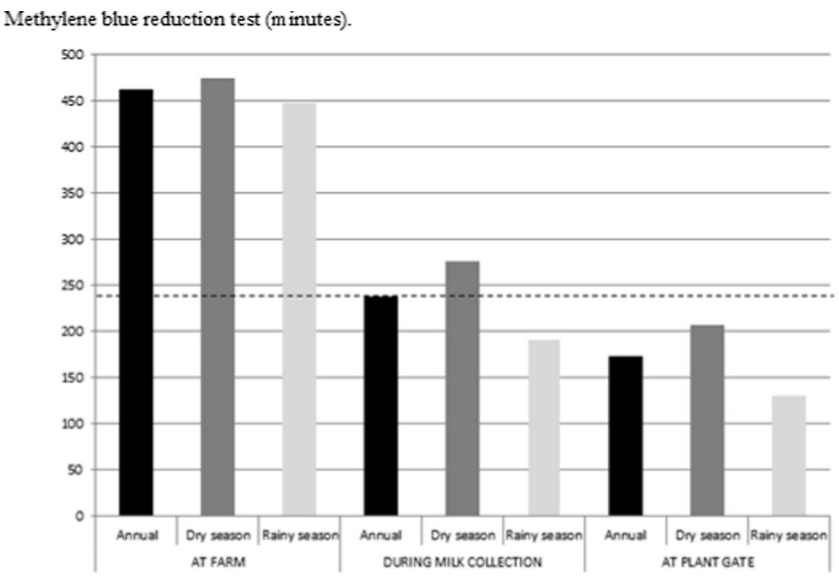



**Fig. 5** Variation in hygienic milk quality at Mantaro Valley. Milk samples were analyzed three times separately: at farm level, during milk collection after almost 12 h under Mantaro Valley's conditions and at plant gate, using methylene blue reduction test (minutes). *Broken lines* indicate minimum recommended value for Peru

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**Table 4** Quality control practices adopted by dairy processors

| Processor practices | Multinational company | Medium-scale formal processor | Small-scale formal processor | Informal processor |
|---|---|---|---|---|
| Clean containers before milk collection | ■ | ■ | ■ | ■ |
| Collection using one container per farmer | ■ | | | |
| Control of chemical milk quality (density) | ■ | ■ | ■ | |
| Control of hygienic milk quality (MBRT) | ■ | | | |
| Fresh milk is not mixed with milk from the day before | ■ | ■ | ■ | |
| Milk is refrigerated at plant gate | ■ | | | |
| Hand disinfection of the personnel at plant | ■ | ■ | | |
| Wear aprons, mask, and hair nets during the manufacturing process | ■ | ■ | ■ | |
| Follow a work protocol for each process | ■ | ■ | ■ | |
| Milk pasteurization before producing dairy products | ■ | ■ | ■ | |
| Use of stainless steel equipment at plant | ■ | ■ | ■ | |
| Sterilization of all the equipment after processing | ■ | ■ | ■ | |

Gray cell indicates that the corresponding practice has been permanently observed

tend to limit their interventions to the basics (Radder and Bhanj 2011). For that reason, plus the lack of training, small-scale farmers also neglected the importance of implementing recommended milking practices. Hygienic status could be quickly improved by including milk quality premium programs (Botaro et al. 2013). However, the adoption of milking practices depends on the balance between the rewards farmers can expect for delivering good milk quality and the extra costs they face when implementing such practices.

### Logistics between farm and plant gate: a key issue for hygienic quality

As shown in this study, hygienic milk quality may deteriorate during its collection because of many interacting logistical factors. Collecting milk in big containers once a day lead to the mixing of fresh milk and milk from the previous afternoon at plant gate and the mixing of individual milk batches during collection, which result in an overall deterioration in hygienic quality of the whole batch (Samal and Pattanaik 2014). Delays between fresh milk collection at farm gate and plant delivery, as well as use of unclean containers, also contribute to this deterioration trend. Moreover, the negative impacts of these practices increase with the absence of a cold chain, especially during the warmer season. These contexts are common where the informal sector predominates, since stakeholders show poor hygienic management and hygienic milk quality is deeply affected by environmental and working condition (Belli et al. 2013).

Considering that cheese is the main processed product of many Peruvian dairies and that higher levels of somatic cells have negative effects on cheese yields (Sharma et al. 2011), milk collected should be better analyzed before being accepted. The next step would be to support processors in improving their logistics, which include reducing collecting routes, collecting twice a day or establishing cooling facilities at key points, and moving from plastic to aluminum containers. Such investments may be costly in dairy areas dominated by many small-scale farmers. In that case, establishing farmers' associations managing intermediate collecting centers can be an efficient solution (Le Gal et al. 2007).

## Conclusions

In such a production context, milk chemical and hygienic quality is rather an uncontrolled output of stakeholders' management processes than a controlled process based on recommended practices. At farm level, some factors such as climatic conditions during the year and farm size affect quality performances, but not always as expected. Chemical quality is affected differently by feeding practices according to cow breed, but it will remain difficult for farmers to control, whatever the kind of farm.

Although processors have to deal with large quality variability of milk, most of them do not implement logistical practices

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that are focused on delivering the best quality milk from farm to plant gate. However, targeting high-valued markets, such as urban supermarkets or facing the risk of public regulation being applied, should push all stakeholders to upgrade milk quality by implementing training and quality control programs, organizing logistics that improve milk quality, and offering incentives such as milk quality-based payment systems.

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**Conflict of interest** The authors declare that they have no conflict of interest.

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**Article 3: Supporting small-scale dairy plants in selecting market orientations and milk payment systems.**

Fuentes, E.[1], Bogue, J.[2], Gómez, C.[3], Vargas, J.[3] and Le Gal, P.-Y[1].

[1]Cirad, UMR Innovation, 73 Avenue Jean-François Breton, 34398 Montpellier, France

[2]Department of Food Business and Development, University College Cork, Cork City, Ireland

[3]Universidad Nacional Agraria La Molina, Apartado 12-056, Lima, Peru.

## Abstract

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 strategic issues that dairy processors face in interaction with their suppliers and buyers, i.e. selecting their product portfolio according to markets opportunities and 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 simulation tool called DairyPlant developed with Excel. DairyPlant calculates the daily profit obtained by a dairy processing unit and the daily gross products 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 with two small-scale dairy plants in the Mantaro Valley (Peru). It showed the processors that (i) they could increase their total profits by modifying their current portfolio towards higher value products, assuming milk delivered to the plant attains a given quality; (ii) they do not pay correctly farmers who deliver good quality milk and overpay some bad quality milk; (iii) their profits would not be affected by adopting 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.

**Key words:** Computer model; processing; dairy products; incentives; payment scheme

## 1. Introduction

In both developing and developed countries small-scale firms dominate in the agricultural sector (Nichter and Goldmark, 2009). They generally have difficulties to satisfy high-value agro food markets requirements (Kirsten and Sartorius, 2002), while using their technological assets in a cost effective way (Cuevas, 2004). Lack of managerial ability and knowledge on coordination management and processing techniques impact on stakeholders' performances and usually lead small-scale firms to inefficient production and inflated costs (Li, 2012). Dairy sector confront the same sort of issues aggravated by features such as limited control of milk quality along the chain, risk of unpunctual processor's payment to farmers, and few processors' incentives for encouraging farmers to produce good milk quality. This overall situation excludes small-sized dairies from urban retailers such as supermarkets and makes both farmers and processors more sensitive to economic shocks (Mather, 2005).

Providing financial and non-financial support can help small-scale dairies in performing well and being more competitive (Beyene, 2002). This support can take various components such as processing techniques, accountability and firm management, which can be met by training sessions and usual management tools such as spreadsheet budget applications. Nevertheless, there is also a need to develop support regarding strategic issues such as market orientation and design of payment system (Bennett et al., 2006), a domain much less investigated for small-scale firms (de Carvalho and Costa, 2007). In that respect, modeling combined with scenario analysis may be instrumental for helping managers in evaluating the best strategic decisions to make (Le Gal et al., 2011), both in terms of products to be processed and incentives such as quality-based payment systems of milk to be implemented towards dairy farmers.

This study presents a decision support tool called DairyPlant developed for supporting small-scale dairies in (i) improving their economic profitability by selecting relevant market orientations and (ii) reinforcing their coordination processes with dairy farmers by designing alternative milk quality payments systems. The study was conducted in a Peruvian Andes area, where an increased annual milk production has been observed but where farmers and processors still show little concern for

quality norms. After describing the rationale of the approach, the software objectives and its conceptual basis are presented. Then, its structure and data processing are described. Finally, the use of the software is illustrated with some cases.

## 2. Rationale

Small-scale dairy processors in developing countries interact in formal and informal chains according to their type of targeted markets and control processes (Farina et al., 2005). Depending of the milk availability in the area and the demand of dairy products throughout the year these chains may compete for ensuring permanent milk supply. This situation plus the fact that there is not any formal contract between stakeholders, lead small-scale dairy processors to apply strategies to secure milk suppliers (Siqueira et al., 2008) e.g. offering attractive prices to farmers or paying bonus for good milk quality. 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 the type of products to be processed, from raw milk to much sophisticated dairy products. Processing costs, input and output costs and milk quality may become critical aspects for benefiting from the market orientations they plan.

In developing countries milk payment is based on quantity rather than quality (Espinoza-Ortega et al., 2007; Gorton et al., 2006). Nevertheless, quality requirements of formal markets start pushing stakeholders to demand higher levels of raw milk quality. The establishment of successful milk quality premium programs can attract new dairy suppliers, motivate the rest of milk producers to 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). Certainly, most of small-scale dairies are currently facing many operational issues common in small-scale firms, such as the availability of adequate technical and economic knowledge and data (Le Gal et al., 2003). But the use of a supporting tool adapted to the dairy production in these areas and dedicated to strategic issues such as the design of alternative payment system, could contribute to increase their mid-term profits on one hand, and encourage dairy farmers to improve their milk quality to get a better income on the other hand (Garrick and Lopez-Villalobos, 2000).

In the last decades, the use of different simulation models has allowed dairy industry worldwide to evaluate “ex-ante” potential solutions to given 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 models have been used for better understanding dynamics between stakeholders and designing efficient dairy supply organizations, which would increase market share, reduce cost, increase profitability and enhance milk quality (Tripathi, 2011). In other industrial sectors simulation tools have supported the design of new payment schemes (Lejars et al., 2010), a better cooperation in negotiation agreements (Foroughi, 2008) and have facilitated strategic discussions between stakeholders (Hall et al., 2007; Le Gal et al., 2008). Despite all these benefits, few reports exist in the literature regarding simulation tools adapted to and used with small-scale dairy processors or considering milk quality-based payment systems in developing countries. The approach described in this paper and based on the design of a simulation tool called DairyPlant attempts to contribute to this issue.

**Table 1.** Simulation models reported around the world for the dairy processing sector (source: Geary et al., 2010)

| Type of model | Objective | References |
|---|---|---|
| **Cost model** | Calculate the cost for specific dairy activities and processes. | Krell and Wietbrauk, 1993. |
| **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 |

## 3. Material and Method

DairyPlant was designed based on a participatory research conducted with five small-scale dairy processors in the Mantaro Valley (75º18´ longitude West; 11º55´ latitude South; 3,200 meters above sea level) in Peru's central Andean region. They were monitored weekly from May to July 2013 in order to estimate production functions from raw milk to dairy product. Then, two of them were selected, based on their willingness to adopt innovative incentives, to carry out the support process and to discuss the feasibility to implement payment systems including milk quality components.

This process included the following steps. Firstly, the support process, its objectives and the general idea behind the simulation tools 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 product produced, price of dairy products, cost of processing dairy products, as well as qualitative ones, such as ways of selecting processed products and paying farmers. These data were used both to design a software structure able to cope with a variety of dairy cases, and to construct a base scenario as close as possible to each given case.

The base 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 and/or if a lack of consistency was detected. Once a satisfactory representation of the manufactured process was achieved, the construction of alternatives scenarios jointly with the processor began. Building alternatives scenario included modifications in (i) processor' current portfolio towards higher value products; (ii) the volume of milk collected per day and (iii) the payments to his milk suppliers. Outputs from these alternative scenarios were discussed and the support process was evaluated with the processor in a final meeting.

## 4. DairyPlant description

### 4.1. General overview

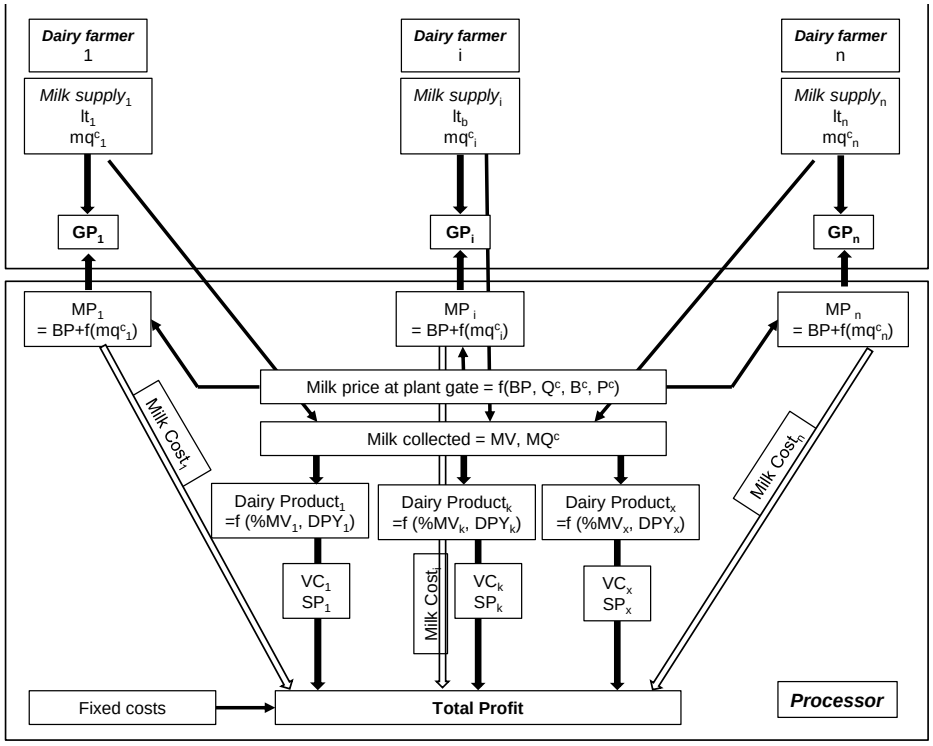
DairyPlant aims to support individually small-scale dairy processors in comparing various marketed product portfolios according to their own objectives such as diversifying their range of products, modifying their processing unit or maximizing their returns. It also allows the design of milk payment systems based on volume and milk quality composition, allowing processors to evaluating the impacts of a given system on their profits. DairyPlant also includes an evaluation of each milk supplier's gross product in order to look for solutions which could improve both stakeholders' economic results. Each simulated scenario provides hypothetical values linked to the dairy circumstances (total milk quantities and quality collected daily, variable and fixed costs for each processed product) and each milk supplier's daily supply in terms of quantity and quality. These output values provide the base for discussions with dairy processors and potentially farmers if they are included in the support process.

DairyPlant represents the milk supply from farm to plant gate and the manufacturing process, by considering the volume of milk collected daily by a given processor (Figure 1). Each milk supplier, should-it be an individual farmer, a group of farmers or a private collector, is characterized by (i) his daily milk quantity supplied to the dairy processor; (ii) his values of up to three quality components (milk composition or milk hygienic values); and (iii) his capacity to increase, decrease or keep his current quality levels if the payment system is changed. This capacity is subjectively assessed by the processor based on the knowledge he has of his suppliers, since there is no direct mathematical relation included in the software between the variation of the payment system and the modification of milk quality supplied by each supplier.

DairyPlant calculates the outputs of the dairy manufacturing process based on (i) the total raw milk collected into dairy products, (ii) its average quality components and (iii) processing equations specific to each processed product. The proportion of milk used in the production of each dairy product is entered by the software user according to the product portfolio selected for a given scenario. The list of product manufactured allows the introduction of intermediate products in the analysis e.g. cream for butter or whey for ricotta cheese. The yield of each dairy product, i.e. the quantity of milk or intermediate product required to produce 1 kg of dairy product, is also defined by the software user based on existent formulas or in-situ controlled experiments. Processing costs are split into milk collection, product-related processing, packaging and marketing costs. Each fixed cost is also defined

and split between processed products according to each processor's choice. At the end of the simulation, processors obtain the total profits related to a given dairy portfolio. Up to 10 marketed dairy products and 5 intermediate processed products can be included in scenarios.

DairyPlant also allows the design of a milk payment system for a plant. It includes a milk base price plus a combination of up to three quality variables, either chemical or hygienic, assuming that these variables are actually measured at the plant gate and so defined for each supplier. For each variable the user gives the base value and a penalty and/or bonus for each point respectively above or below the base value. So, simulations may include payment systems with (i) only bonuses and no penalties; (ii) both; or (iii) a fixed base price only. The calculation of milk cost for the processor and of gross product for the suppliers can then be carried out according to the quality supplied by each one to the plant. Suppliers' profits are not calculated since it is considered that processors usually do not have access to their private cost information.




**Farmer's variables**
$lt_i$= Liters of milk delivered by farmer *i*
c = Milk quality component
$mq^c_i$ = Value of milk quality component *c* for farmer *i*
$GP_i$ = Gross product of farmer *i*

**Processor's variables**
BP = Base milk price per liter of milk
$Q^c$ = Base value for quality component *c*
$B^c$ = Bonus value for +1% of quality component *c*
$P^c$ = Penalty value for -1% of quality component *c*
$MP_i$ = Milk price paid to farmer *i* for his milk quality
MV = Total milk volume collected
$MQ^c$= Average value of quality component *c* for MV
$\%MV_k$= Proportion of MV dedicated to Dairy Product *k*
$DPY_k$= Process yield for Dairy Product *k*
$VC_k$ = Variable costs for Dairy Product *k*
$SP_k$ = Sale price of Dairy Product *k*

**Figure 1.** Schematic representation of DairyPlant

### 4.2. The spreadsheet simulation tool

#### 4.2.1 General presentation

DairyPlant was developed using Microsoft Excel® 2010, in a user-friendly way in order to facilitate its manipulation and understanding by the stakeholders involved in the support process. It is split into three modules (Table 2): “Parameters” (variables which take the same value for a group of plants), “Input” variables (specific to one given plant: range of dairy products, milk quantity and quality per famer, payment system, costs and gross product per dairy product) and “Results” (calculated variables for the given case: plant profit and farmers’ gross products). Each module is split into several sheets according to the kind of information required or provided. Each scenario is described and run for one day considered as representative of the plant business throughout the year, and saved in one Excel file. The software is available in three languages: English, French and Spanish.

A table of contents is presented after the welcome page, describing the information about each sheet of the application. A range of colors are used to characterize different groups of cells according to their content names, parameters and input variables, output variables. Parameters and input cells can be filled either manually or from a list defined by the user himself. The user can move from one sheet to another by going back to the content sheet and by clicking on the required sheet in the list provided, or by using downward and forward icons included at the top of each sheet. A “reset” icon is also provided to delete input values in one sheet or in a whole scenario.

**Table 2**: **Commented list of the variables included in DairyPlant**

| Tool module | Variable name | Comments |
|---|---|---|
| Parameters[1] | Dairy Product | List of the processed products encountered in the area |
| | Quality component | List of the milk quality components likely to be included in the payment system (ex: Fat) |
| | Quality improvement | List of farmers' expected reaction if a payment system is implemented |
| | Variable Cost Milk | List of costs related to manufacture of dairy products (ex: Rennet, lactic culture, milk powder, etc.) |
| | Variable Cost Process Product | List of costs related to marketing of dairy products (ex: package, label, etc.) |
| | Fixed Cost | List of costs which are independent from the quantity of milk collected |
| | Process Yield | List of dairy products, yield values and raw products used in the manufacture of these dairy products |
| Input variables[2] | *Plan scenario* | |
| | Plant name | Appears on every sheet |
| | Scenario name | Appears on every sheet |
| | Payment System | Base price per liter of milk and the bonus and/or penalties for up to 3 milk quality components. |
| | Dairy Products | Selection of marketed dairy products and intermediate processed products manufactured. Percentage of milk quantities for each one. |
| | *Supply* | |
| | Farmers' name | Possibility to introduce up to 100 dairy farmers with their respective liters of milk delivered per day. |
| | Quality component | Data is introduced per farmer or from the bulk tank |
| | Quality improvement | Used to simulate scenarios with hypothetical milk quality variations. |
| | *Plant fixed costs* | Selection and distribution of fixed costs between all dairy products manufactured. |
| | *Marketed products* | |
| | Product name | Similar for the 10 excel sheets |
| | Sale price per unit | Appears on every sheet |
| | Milk cost | Price according to current processors' sales |
| | Variable processing costs | Based on the total amount of dairy product manufactured |
| | Variable marketing costs | Selection of manufacturing costs for the specific dairy product |
| | Fixed costs of the product | Selection of marketing costs for the specific dairy product<br>Completed automatically from "Plant fixed costs" data |
| Output variables[3] | *Plant results* | Summary of "Plant scenario" data plus production yield, total quantity produced, gross product, total cost, total profit and profit per unit of each one of the dairy products marketed |
| | *Farmer results* | Summary of "supply" data plus milk price, premiums and penalties, and gross product of each dairy farmer. |

[1] Variables which take the same values for a group of plants
[2] Variables which take a value specific of the plant supported and the scenario simulated
[3] Variables which take a value calculated from Input and Parameter variables

#### 4.2.2. The "Parameters" module

The "Parameters" module is split into two sheets. The first one includes variables required in the "Input" module for characterizing a given scenario. Each variable may take a range of values that are defined by the user: the list of possible processed dairy products, milk components involved in the quality evaluation (e.g. protein, fat, total solids), the perception of quality improvement per farmer (e.g.

=, + or -), and the fixed and variable cost items related to the processing or the marketing of dairy products. These values constitute lists that are active in some input cells, where they can be selected by the user according to a given scenario.

The process yield values $DPY_x$ are entered in the second sheet for each possible dairy product defined in the first sheet (Figure 2). The user defines the raw material used and the quantity of raw material required to produce one kg of a given processed product. This quantity is based on existent formulas or controlled experiments. These formulas can include milk quality components when they impact the processed yield (see equation (1) for an example with Andean cheese). These processing yields are essential to determine the amount of dairy products produced by a processor, based on both the collected milk quantity dedicated to each dairy product and its average quality of all the daily deliveries.

$$DPY_{AC} = (2.8826 + (0{,}5015 \times \overline{TS}))/1{,}028 \quad (1)$$

Where:

$DPY_{AC}$ = Andean cheese yield (kg milk / kg of processed product)

$\overline{TS}$ = Average value of total solids for all the daily deliveries

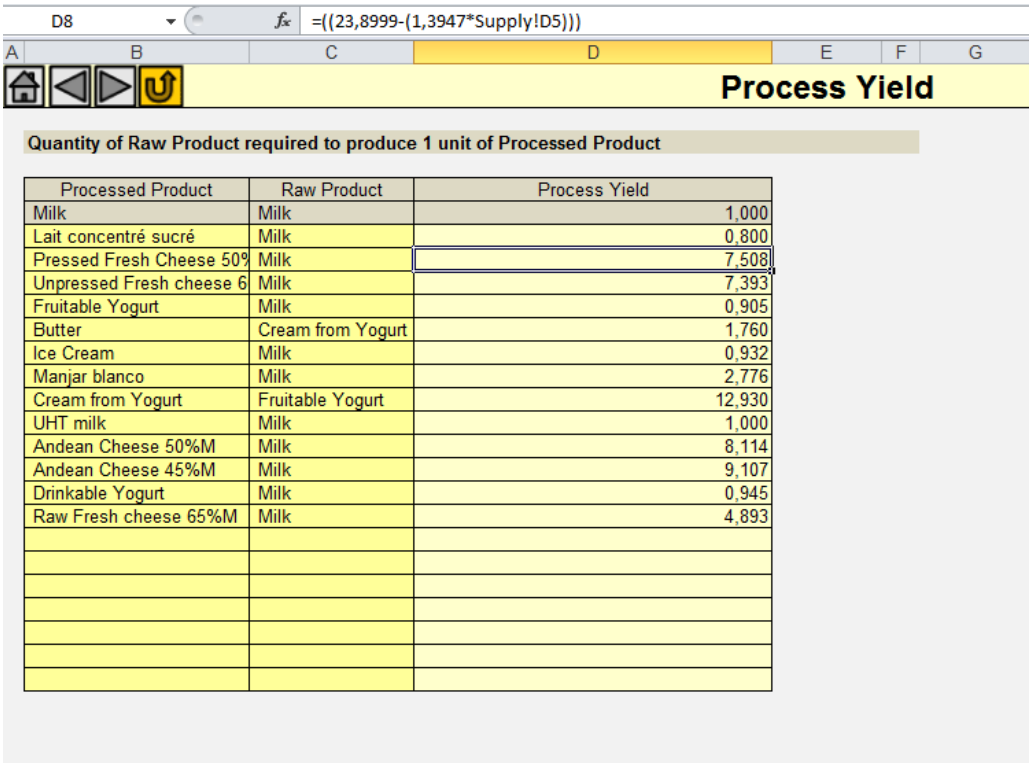



**Figure 2:** “Process Yield” sheet

4.2.3. The “Input” module

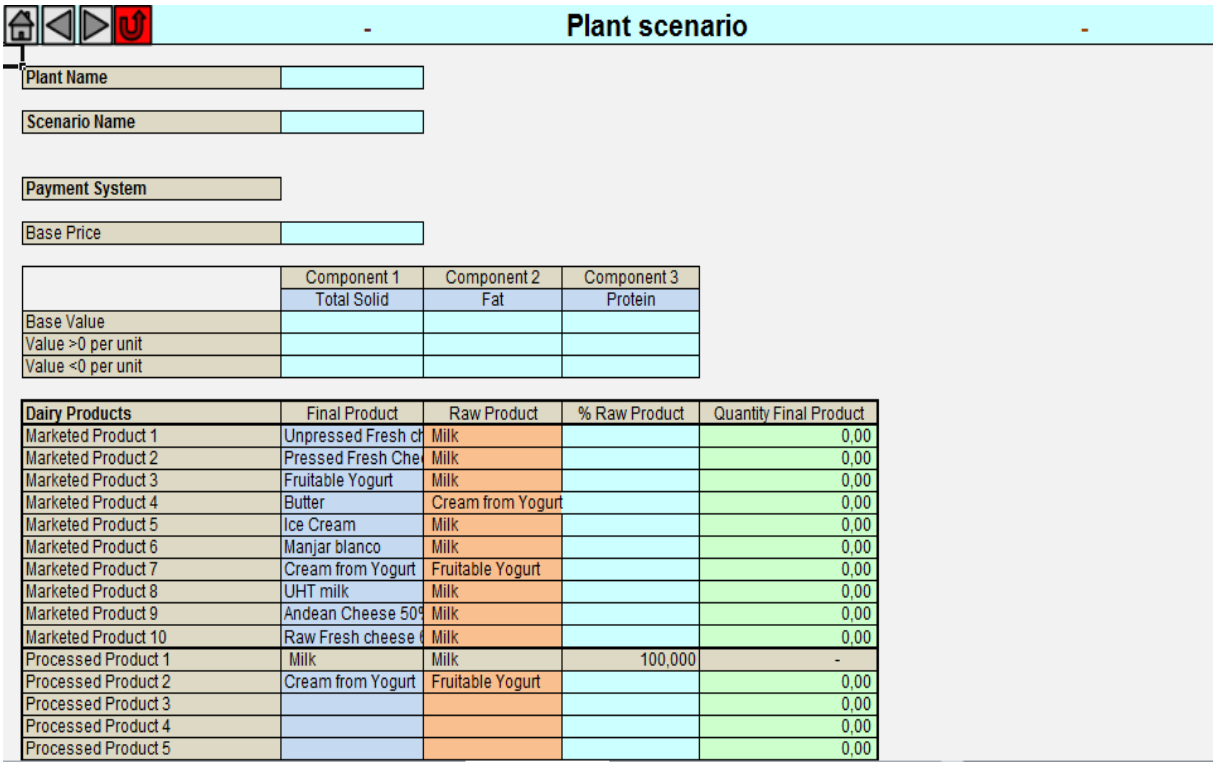
The “Input” module is divided into four sub-modules: Plant scenario (1 sheet), Supply (1 sheet), Fixed costs (1 sheet) and Marketed products (10 identical sheets, one per product). In the “Plant scenario” are entered the plant and scenario names, that are then reminded at the top of the other “Input” and “Output” sheets. It also includes the type of payment system applied (Figure 3). The software user enters at least a base price, and optionally a base value (%) for up to three milk components and the economic value of each point respectively higher (bonus) or lower (penalty) than the base value. A table allows to defining the list of dairy products that processors are or would like to produce, the raw material for each dairy product and the proportion of raw product (milk or intermediate) used in the process. This list is linked to the processing yields sheet to calculate the final quantity of each dairy product (Eq.3).

$$Quantity_DP_k = MV \times \%MV_k \div DPY_k \quad (2)$$

Where:
$Quantity_DP_k$ = Total quantity of dairy product *k*
$MV$ = Total volume of milk (or intermediate product)
$\%MV_k$ = Proportion of MV dedicated to produce dairy product *k*
$DPY_k$ = Processed yield for dairy product *k*

(ii) The “Supply” sheet regroups information regarding suppliers’ daily milk delivery. Up to 100 suppliers can be defined. For each of them, the user enters his daily volume and the milk quality values for the 3 components selected in the “Plant Scenario” sheet. The total volume of milk collected in a day and the weighted average values of milk quality composition are then calculated for the plant. The user can also introduce the plant values directly should farmers’ individual figures be unknown by the processor. In that case, DairyPlant is mainly used to evaluate and compare various scenarios of market orientations. Quality improvement is qualitatively defined by the processor based on his knowledge about his suppliers’ behavior regarding milk quality management. It is there as a reminder for the user to change subjectively and hypothetically the quality values of each farmer if a given payment system is applied. This flexible procedure is based on the principle that a quality-based payment system will affect farmers’ behavior and performances. But without mechanistic relation regarding these changes the range of variation for each quality component is left to the user’s appreciation.

(iii) In the “Fixed costs” sheet are entered all the costs which are independent from the quantity of milk collected per day. The user chooses the kind of costs in the list entered in the ”Parameter” sheet, the total amount of each cost and its distribution between the 10 possible marketed products based on the processor’s evaluation of this distribution. (iv) Each “Marketed product” sheet represents the daily processing of one dairy product. The market value of a dairy product can be modified to simulate different scenarios of price. Fixed costs are calculated based on the figures entered in the “Fixed costs” sheet, while variable costs are entered based on two categories: the costs related to ingredients used for processing raw material, such as salt or bleach, and the costs related to the packaging and marketing of the final dairy product. When milk is the raw material used, its purchase cost is calculated according to the quantity used multiplied by the average price paid for the total milk quantity collected daily.



Plant scenario

| | |
|---|---|
| Plant Name | |
| Scenario Name | |
| Payment System | |
| Base Price | |

| | Component 1 Total Solid | Component 2 Fat | Component 3 Protein |
|---|---|---|---|
| Base Value | | | |
| Value >0 per unit | | | |
| Value <0 per unit | | | |

| Dairy Products | Final Product | Raw Product | % Raw Product | Quantity Final Product |
|---|---|---|---|---|
| Marketed Product 1 | Unpressed Fresh ch | Milk | | 0,00 |
| Marketed Product 2 | Pressed Fresh Che | Milk | | 0,00 |
| Marketed Product 3 | Fruitable Yogurt | Milk | | 0,00 |
| Marketed Product 4 | Butter | Cream from Yogurt | | 0,00 |
| Marketed Product 5 | Ice Cream | Milk | | 0,00 |
| Marketed Product 6 | Manjar blanco | Milk | | 0,00 |
| Marketed Product 7 | Cream from Yogurt | Fruitable Yogurt | | 0,00 |
| Marketed Product 8 | UHT milk | Milk | | 0,00 |
| Marketed Product 9 | Andean Cheese 50° | Milk | | 0,00 |
| Marketed Product 10 | Raw Fresh cheese ( | Milk | | 0,00 |
| Processed Product 1 | Milk | Milk | 100,000 | - |
| Processed Product 2 | Cream from Yogurt | Fruitable Yogurt | | 0,00 |
| Processed Product 3 | | | | 0,00 |
| Processed Product 4 | | | | 0,00 |
| Processed Product 5 | | | | 0,00 |

**Figure 3:** “Plan scenario” sheet

#### 4.2.2. The results module

Once the scenario is characterized, DairyPlant simulates the corresponding milk processing of the dairy plant. Results are presented in two separated sheets called “Plant results” and “Farmer results”

respectively (Figure 4). based on (i) ; the total production costs (fixed and variable) linked to the dairy plant operation; the adjusted milk price corresponding to each farmer after bonuses and penalties and his gross product according to his quantity of delivered milk. This gross product corresponds to the milk cost for the processor.

The “Plant Results” module calculates the profits obtained by the dairy processor according to his product portfolio, his marketing strategy which drives sale prices, and his cost structure. The profit per marketed product is calculated from the following variables: (i) gross product according to the total amount of marketed product and its average sale price, (ii) milk cost for product processed from raw milk, (iii) processing and marketing costs, and (iv) fixed costs when they have been distributed between products. All these variables are sum up to obtain total figures at plant scale. Total fixed costs are directly included when they are not distributed between products. Intermediate materials are not included in the cost structure since they are considered as a free processing by-product. Some indicators are also calculated for each marketed product and at plant scale in order to facilitate the analysis of results by processors: respective share of total costs between milk, variable and fixed costs, profit per unit, respective share of total plant profit between marketed products, and ratio between costs and profits in percentage.

The “Farmer Results” module calculate the gross product of every supplier of the plant based on his amount of milk supplied, multiplied by the purchase price by the plant. This price is calculated according to the payment system entered in the “Scenario” sheet and the individual milk quality figures entered for every supplier in the “Supply” sheet. Each supplier can then assess quickly the consequences of a given payment system on his gross product. Finally, all the results can be copied in a new Excel file for further analysis and graph design in order to facilitate the discussion with processors and eventually farmers.

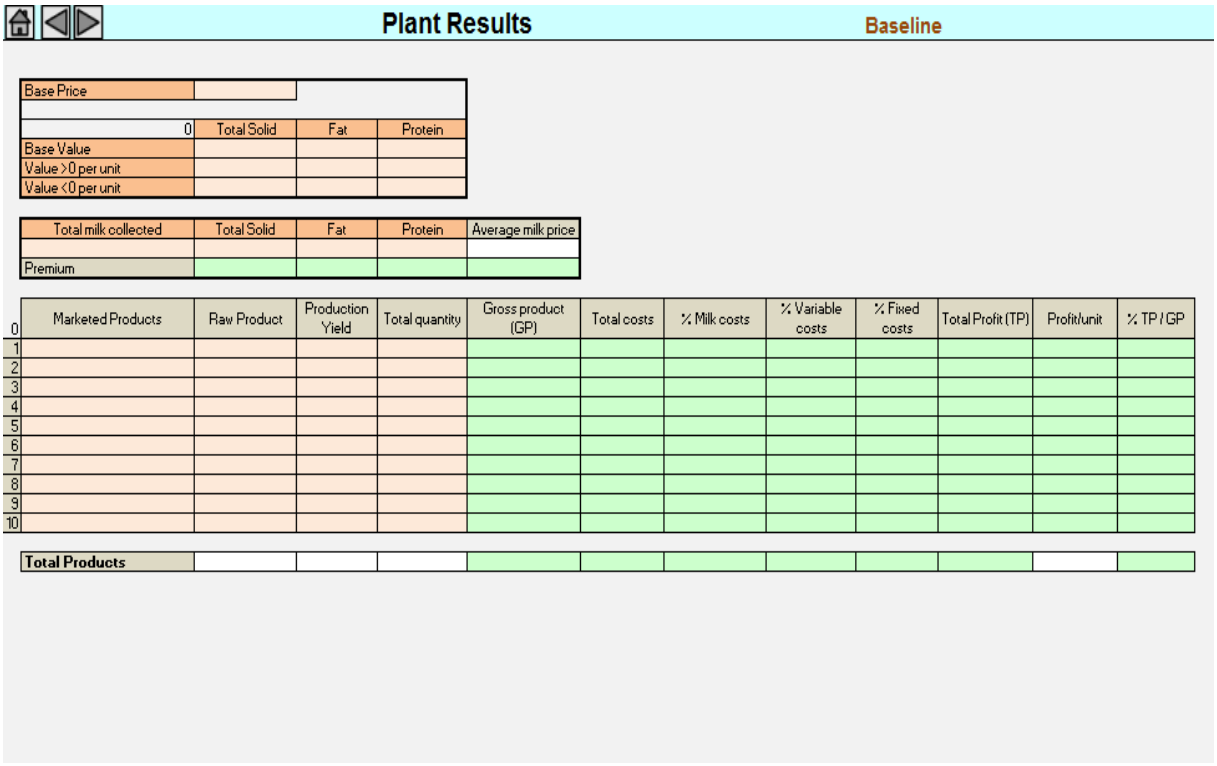



**Figure 4:** “Plant results” sheet

## 5. Illustration of the model: Improving dairies profitability and implementing quality based delivery rules for small-scale producers

DairyPlant was tested with two small-scale dairy plants (DP1 and DP2) in the Mantaro Valley to show them potential benefits they could expect from modifying their current portfolio or from adopting a payment system based on milk quality. Moreover, this approach attempted to develop a prospective thinking with them about milk quality, since they currently neglect the importance of rewarding their milk suppliers and managing milk quality on their manufacturing process. A reference scenario was simulated in each dairy in order for the processor to understand the tool structure and to validate the description of his plant structure and his current operation. Two alternative scenarios were then configured and simulated in order to address two issues for their potential impact on the plant total profit: diversifying marketed product portfolio towards higher added-value products, and introducing quality-based payment system. Moreover a simulation process was conducted on a virtual dairy plant to assess the impact of introducing a season-based payment system.

*Product portfolio*

Fresh cheese is the main manufactured product of Peruvian dairies. While it represents between 70 to 80% of the milk processed, it does not necessarily provide the highest profits. Various scenarios based on the different distribution of raw milk between alternative products were evaluated. The scenarios varied according to the amount of milk processors were able to divert from fresh cheese towards other dairy products and the total profit expected at the end. Results show that both DP1 and DP2 can have better profits if they diversify their product portfolio (Table 3). DP1 profits may increase by 65% after reducing 45% the milk used to produce fresh cheese by producing more aged cheeses, yogurt and majarblanco (a product based on the reduction of milk and sugar). DP2 obtained 60% more profits by replacing 20% of the milk from fresh cheese to produce aged cheese.

The two dairy processors also suggested the simulation of processing more milk volume in order to keep their level of fresh cheese manufactured. DP1 increased its profits by 45% and DP2 by almost 100% if they collect one third more of milk. Nevertheless, competition for milk supply in the area will make this second alternative impossible. Indeed, a deeper on field evaluation about the feasibility of these two alternatives i.e. processes more milk or expanding other markets could be instrumental as a complement of our findings.

**Table 3: Simulation of the variation of product portfolio and milk volume collected from two small-scale dairy processors at Mantaro Valley**

| | | Dairy processor 1 (DP1) | | | Dairy processor 2 (DP2) | | |
|---|---|---|---|---|---|---|---|
| Variable | | Reference scenario | Scenario 1 | Scenario 2 | Reference scenario | Scenario 1 | Scenario 2 |
| Milk collected (liters/day) | | 950 | 950 | 1300 | 450 | 450 | 600 |
| Number of suppliers | | | | | | | |
| Distribution of raw milk at plant gate (%) | Fresh cheese | 81 | 45.5 | 81 | 70 | 57.7 | 70 |
| | Yogurt | 8 | 25 | 8 | 26.5 | 26.5 | 26.5 |
| | Manjarblanco | 2 | 15 | 2 | 0 | 0 | 0 |
| | Aged cheese | 4.5 | 10 | 4.5 | 2.5 | 15 | 2.5 |
| | Ice cream | 4.5 | 4.5 | 4.5 | 1 | 1 | 1 |
| Total profit / day ($) | | 340.7 | 561.5 | 491.5 | 51.1 | 80.0 | 99.3 |

Bold values represent the distribution of raw milk from fresh cheese to the rest of dairy products

*Quality-based payment systems*

Milk chemical composition was measured per farmer supplying DP1 and DP2. Based on these figures, an average value of 11.6% total solids () was chosen in both cases as the base price of a qualitative-based payment system of milk. In the reference scenario, up to 70 percent of dairy farmers receive lower milk prices than they should receive and around 25-30% of them are overpaid. Although the lack of milk chemical quality control seems to be advantageous for dairy processors, this situation is quite risky since the farmers underpaid could prefer to join a processor who offer higher milk prices in a context of high competition for milk.

Simulation of a quality-based payment system considering an increase of 0.3% of total solids after the implementation of a bonus of 0.03 per unit above 11.6% and a penalty of 0.10 per unit below showed differences on dairy processor total profits of less than 5%, mainly because the two small-scale dairy processors analyzed receive already milk with adequate level of total solids. Nevertheless, the simulation gave to small-scale dairy processors the possibility to better estimate the maximum amount of money they can pay per liter of milk to each of their dairy farmers. Moreover, dairy processors realized that if they apply a quality-based payment system they will be reducing the overpaid farmers, rewarding correctly farmers who provide good quality and ensuring suppliers' loyalty without increasing considerably their milk cost.

*Simulation of economic processors' impact according to the seasonal variation*:

Milk production in the Peruvian Andes is affected by seasonal variations. In the rainy season, milk availability is high due to good forage production. In the dry season milk production is lower and processors compete to collect enough volume. How these variations impact on dairy profits was simulated considering a virtual small-scale dairy which process 950 liters of milk per day and collect milk without significant variations in chemical quality (Table 4). Three scenarios were designed for each season: (i) keeping the same milk price but collecting 15% less of milk, (ii) increasing the milk price by 15% with the same amount of milk collected; (iii) decreasing milk collection by 15% while increasing milk price by 15%. These three scenarios may potentially occur in the two seasons

because of competition between processors to buy milk in dry season, and between farmers to sell milk in rainy season.

Results highlight the sensibility of small-scale dairy processors to the seasonal variation and the importance to manage different strategies throughout the year. During dry season, offering dairy farmers an extra payment of 15% per liter of milk to keep the same amount of milk collected can provide more profits comparing than keeping the same milk price but losing 15% of milk collected. Similarly, processors' profits can be affected by more than 40% if higher competition for milk force processors to increase by 15% the price per liter of milk while they reduce by 15% the milk collected. An opposite situation occurs during rainy season, where profits can be increase until 50% if processors collect 15% plus and pay 15% less per liter of milk. Nevertheless, the feasibility of this second scenario will depend from the availability of suppliers to accept a reduction on milk price and the processors' capacity to process and sell the surplus of dairy products produced.

**Table 4: Performances variations of a virtual small-scale dairy processor at Mantaro Valley* according to the season of the year**

| Season | Scenarios | Total Profit per day ($) | Efficiency (%) in relation to the standard scenario |
|---|---|---|---|
| Optimal | Standard situation | 270 | 100 |
| Dry season | -15% milk collected, but keeping the same price per liter of milk | 205 | 76 |
| | Same milk collected plus 15% of price per liter of milk | 212 | 79 |
| | -15% milk collected plus 15% of price per liter of milk | 156 | 58 |
| Rainy season** | +15% milk collected, but keeping the same price per liter of milk | 335 | 124 |
| | Same milk collected, and -15% of price per liter of milk | 328 | 121 |
| | +15% milk collected, and -15% of price per liter of milk | 401 | 149 |

* Simulation of a dairy processing 950 kg. of milk per day without significant variation in milk quality composition through all the year

** Values assuming a constant demand for extra dairy products produced

## 5. Discussion

DairyPlant can be seen as a simple dairy processing model compared to the sophisticated predictive models used by the dairy industry in developed countries. However, the transparency of this simulation tool and its use as part of participatory support approach favored the active involvement of

small-scale dairy processors in the construction of the spreadsheet application and the alternative scenarios, and in the discussion of possible implementation of the alternative scenarios simulated quality payment systems. Indeed, such tools allow processors to quickly assess how their profits would be impacted by different scenarios while understanding clearly how calculations have been carried out to obtain a given result. As such DairyPlant is close to the companion modelling approaches which try to avoid the “black box” effect of complex models (Voinov and Bousquet, 2010).

However, DairyPlant show two main limitations. Firstly, mechanistic relationships between payment system and farmers’ quality changes were not included in the analysis. Indeed, such relationship is difficult to establish in a specific production context, since it is technically uneasy to link feeding or milking practices to a given quality value (Fuentes et al., 2014). However, changing practices needs for the farmer that extra-costs will be compensate by better milk price (Valeeva et al., 2007), which complicates the modeling of such a relationship. Botaro el al. (2013) reported similar constraints regarding changes in milk composition after rewarding dairy producers. (ii) Calculation in the farmer’s results sheet were not related to farmers’ profits but to farmers’ gross products. The analysis does not include individual farmer’s production costs because it would assume that either the dairy processor knows this private information, or farmers agree to give it in a negotiation process with the processor. Since information on individual production costs is a strategic resource both on farm and dairy sides in such a negotiation, it seems unnecessary to integrate it in DairyPlant.

The use of DairyPlant could favor the transparent relationship between farmers and processors, especially in areas where there are lack of sufficient knowledge about milk collection and processing aspects. Dairy processors can benefit from the use of DairyPlant by testing various strategies of product portfolio and payment systems without any economic risk. Scenarios combining alternative portfolios and payment systems could be considered since both aspects are linked. Indeed, some dairy products require better milk quality, which could be rewarded by a better payment system, which would secure profits of farmers who are ready to implement quality management strategies. Moreover, the simulations may allow processors to taking into account the diversity of farmers based on their quality performances and capacity to improve, and to implement targeted strategies towards farmers who have difficulties to reach given standards, such as specific advices or input supply programs.

The first use of DairyPlant caused a positive reaction from the small-scale dairy processors involved in the study. Indeed, managing milk manufacturing processes and planning quality incentives systems were unknown concepts by stakeholders when this study started. Implementing the support approach helped them to clarify their ideas about these concepts. Most of processors realized the need to control milk quality, since it has a direct effect on their performances and economic revenues. However, they also objected that putting more control could push milk suppliers towards processors who are less interested by quality aspects. In such context, the implementation of simple quality-based payment systems that guarantees win-win scenarios for most of the stakeholders could be a key element. But success will depend on the clear understanding of the rules from all the stakeholders' involved (Lejars et al., 2010), the application of attractive incentives to discourage unfavorable changes in chemical milk composition, and the confidence of both farmers and processors in the quality measurement protocol put in place to provide the individual values required for such a system.

## 6. Conclusions

DairyPlant is a simulation tool focusing on key issues governing raw milk flow from dairy farms until processing plants. The model was designed to provide support to small-scale dairy processors in two specific aspects: (i) to analyze the plant processing management and (ii) to evaluate the possibility of applying milk quality payment systems. Attributes of this support tool include the highly participative nature of the approach, and the assessment and comparison of various alternatives. DairyPlant has been developed as a user-friendly software in order to be used by a large number of potential users in developing countries. Its structure allows the easy understanding of the manufacturing process. Moreover, values of processing parameters can be personalized for each small-scale dairy processor circumstance for better accuracy of the results.

Tested with a small sample of dairy processors in the Peruvian Andes, DairyPlant was flexible enough to allow the simulation of a large range of scenarios in a short time. Indeed, few input data are required to run a simulation. DairyPlant was also able to provide knowledge about the impacts of quality-based payment schemes on small-scale processors' profits and farmers' gross products,

assuming data regarding milk composition are available at plant and farmer levels. The results helped processors to develop a critical reflection about quality, his impact on dairy process yield and on profits. Although relationship between farmers' practices and milk composition are not well established, these simulation results helped processors to build a more systemic perspective of the quality issue in the dairy chain.

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# ANNEXES

**ANNEX 1: Questionnaire for small-scale dairy farmers**

Name: Location:

Name of the collecting point: Date:

## I. HISTORICAL ASPECTS OF THE FARM:

When did you install your farm in this area?

What are the main characteristics of your farm (surface, livestock, crops, family work, etc.)?

What are your main reasons to raise cattle?

## II. FARM MANAGEMENT:

### a.- Reproduction:

What type of breed do you have in your herd?. Do you have a system of genetic improvement at farm level? YES or NO. If is YES, Which one?

### b.- Sanitary aspects:

How often do you clean the animal housing?

Do you have a vaccination calendar in your farm? If is YES, which one?

Your herd has faced one of these problems during the last 12 months? YES or NO. Do you have a notebook of treatment records in your farm?

| Fever | Diarrhea | Pneumonia | Distomatosis | Brucellosis | Footrot | Others |
|---|---|---|---|---|---|---|
| | | | | | | |

### c.- Feeding

What is the average diet used to feed your lactating cows (kg./cow/day):

| Feed (forage or concentrate) | % |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |

Your availability of forage or concentrate is affected due to a seasonality variation?. How do you manage it?

Do you have a current feeding strategy to increase your milk production or your % of milk components (fat, total solids, etc.)?

**d.- Milk production:**

How many lactating cows do you have in your farm? Is it a constant number?

How many times per day do you milk your cows?

Total volume produced (per month):

| Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

How many kilograms of milk are produced in TOTAL by your farm per day (in average)?

How many kilograms of milk do you use for auto-consumption (per day)?

How many kilograms of milk are used to feed calves (per day)?

Do you have *a* milking parlour in your farm? If is YES, could you explain how it is designed? If is NO, where do you milk your cows?

Describe what type of facilities and equipment do you have? (Include the material: PVC, stainless steel, etc.)

How is your milking system: Manual or automatic? Could you explain how the milking process is done every day?

Do you have a potable (drinkable) water supply system in your farm? If is NO, how do you obtain it? And what source of water do you use to clean your milking equipment and the parlour?.

Do you follow any hygienical practices in your dairy plant before and during the milking process?. Which ones?

How do you refrigerate the milk after the milking process? Do you control the temperature?

Do you send directly your raw milk to a collecting point or a processor? Or they collect the milk from your farm? If the processor is the one who collects the milk, how many hours take till they arrive?

## III. MARKET:

To whom do you sell your products?

What kind of agreement do you have with your clients (collecting points, dairies, processors, etc.)?. Written contract / oral / other. Under what conditions?

How is the payment system (frequency, in cash or in species)?.

What do you do with the calostrum and the milk that is rejected by your clients?

## IV. RELATIONSHIP WITH OTHER ACTORS IN THE AREA:

Do you have any relationship with other farmers in the area (association, cooperatives, etc.)? What type of relationship do you have? And what are the benefits?

The presence of a big dairy like “Gloria” in the valley has had any impact on the way you produce milk at farm level (due to possible changes in prices, rejection of milk, etc.)? If is YES, it was positive or negative and why?

What is your opinion about PRONAA project? The PRONAA project in the valley has had any impact on the way you produce milk at farm level (due to possible changes in prices, rejection of milk, etc.)? If is YES, it was positive or negative and why?

## V. RELATIONSHIP WITH PROCESSORS:

Which are the criteria used to select the processors?

Do you receive any service as an incentive from the processors?

Do you receive an incentive for produce milk during the dry season?

What strategies do you apply to keep your processor loyalty? Which?

## VI. QUALITY:

What means milk quality for you?

In a scale from 0 to 10 (where 10 = very important) how important is for you to produce a good quality milk?

Are there some specific controls of milk quality in your farm?. If is YES, which ones?

Do you analyze (in terms of quality) the milk produced after the milking process?. YES or NO. If is YES how often do you check it?

Acidity
Density
Fat content
Protein content
Other

The processors do any sort of control/measurement of milk quality at farm level?

From your point of view, in a scale from 0 to 10 (where 10 = very important) how important is for the processors that you keep an adequate milk quality?

Do you receive an incentive (input supplies, credit, advices, training, payment regularity, etc.) or an extra payment according to the milk quality you produce?. YES or NO. If is NO would you be interested on it?

## VII. AIDS OR SERVICES RECEIVED:

Do you receive (or have received) any aid or service from the government or a NGO?. If is YES how? and when?

Do you have access to credit?. If is NO for what reason?

## VIII. OVERVIEW AND PERSPECTIVES:

What are the main constraints you have to face?

What is your priority in terms of production?. Do you have plans to increase the number of cows and / or diversify your livestock?

What perspectives do you have in the future of your farm?

**ANNEX 2: Questionnaire for dairy processors**

Name of the company: Location:

Name of the responsible: Date:

**I. PRODUCTION:**

With how many suppliers (farmers) do you work?:

How many kilograms of milk do you collect per day (in average)?:

What types of dairy products do you produce?

**II. MARKET:**

To whom do you sell your products?

What kind of agreement do you have with your customers?. Written contract / oral / other. Under what conditions?

How is the payment system with your costumers?

**III. RELATIONSHIP WITH OTHER ACTORS IN THE AREA:**

Do you have a relationship with other dairies and cheese factories in the area? What type of relationship do you have?

The presence of a big dairy like “Gloria” in the valley has had any impact on your production? If is YES, it was positive or negative and why?

The PRONAA project in the valley has had any impact on your production? If is YES, it was positive or negative and why?

**IV. RELATIONSHIP WITH FARMERS:**

How much is your average purchase price of milk per kilogram?. Is it affected due to a seasonality variation?

How do you do the milk collection? How many times per day?

Do you have a written contract or a verbal agreement with the farmers?. Under what conditions?

How is the payment system with the farmers?

Do you apply some strategies to keep your farmers loyal? Which?

- Get incentives to farmers, i.e. special payments or bonuses during the offseason?
- Do you provide non-market services to farmers?: training, access to credit, input supplies, etc.
- Other……..……

**V. QUALITY:**

In a scale from 0 to 10 (where 10 = very important) how important is for you to ensure the good quality of your products?

What are the reasons for why do you think it is important to check milk quality and dairy products quality through the processing chain?.

How is the control of milk quality during the processing chain in your dairy plant?.

Do you have any “specification” in terms of quality when you collect the milk?. YES or NO. If is YES how often do you check it?.

Acidity
Density
Fat content
Protein content
Other

Do you have any “specification” in terms of quality when the milk arrives to the plant gate?. YES or NO. If is YES how often do you check it?.

Acidity
Density
Fat content
Protein content
Other

What happens if a farmer does not achieve the required quality?

Do you do any sort of control/measurement of milk quality at farm level?

From your point of view, in a scale from 0 to 10 (where 10 = very important) how important is for your suppliers (farmers) to keep an adequate milk quality?

Do you give a bonus or an extra payment to the farmers according to the quality of their milk?. YES or NO. If is NO would you be interested in adopt this measure to ensure an adequate supply of milk quality?.

From your point of view, in a scale from 0 to 10 (where 10 = very important) how important is the good quality of your products for your costumers?

Do you label your products? If is YES do you provide any information related to milk quality to your customers?

Do you think your customers would be willing to pay an extra for a product which ensures is based with a good milk quality?. If is YES how much?.

**IX. OVERVIEW AND PERSPECTIVES:**

What are the main constraints you have to face?

What is your priority in terms of production?. Do you have plans to increase your capacity and / or diversify your production?

What are your market positioning strategies? Are you looking for selling in Lima, what could be the possible constraints?

What perspectives do you have in the future of your business?

**ANNEX 3: List of management and milking practices**

FARM: DATE:

VARIABLE OPTIONS

**I. - General productivity characteristics**

1. Predominant dairy breed: Holstein / Brown Swiss / Crossbreeds/ Other breeds
2. Total number of cows: <5 cows / 6 – 10 cows / 11 – 19 cows / > 20 cows
3. Milking cows at the time of the evaluation: <5 cows / 6 – 10 cows / 11 – 19 cows / > 20 cows
4. Milk produced per day per farm: <10 lts. / 11 – 25 lts. / 26 – 50 lts. / 51 – 99 lts. / > 100 liters
5. Length of lactation: <8 months / 8–10 months / 8-12 months / >12 months

**II.- Infrastructure and equipment management**

6. Gather the cows in a waiting yard before milking: Yes / No
7. Floor of the waiting yard: Soil / gravel / Concrete
8. Clean waiting yard: Never / At least once a day / Less than once a day
9. Floor of the animal housing: Soil / gravel / Concrete
10. Clean animal housing: Never / At least once a day / Less than once a day
11. Floor material of the milking parlour: Soil / Concrete / Wood
12. Roof material of the milking parlour: Tin / Other (e.g. wood, tiles) / None
13. Location of the milk churns: Outside / In milking parlour / House
14. Milk-cooling system: Milk is not cooled /Tank in water / Cooling tank / Preservatives
15. Frequency of milk collection: Once a day or less / Twice a day
16. Cleanliness of the equipment before milking: Poor / Fair / Good / Very Good
17. Cleanliness of the equipment after milking: Poor / Fair / Good / Very Good
18. Material of the milking pail: Metal / Plastic

**III.- Sanitary and milking practices**

19. Keep a notebook of treatment records: Yes / No
20. Cows are milked: By hand / By machine
21. Frequency of milking liners cleanliness during milking: At the beginning / Between cows / At the end of the milking

22 Udder examined before milking: Never / Always / Sometimes

23. Method of udder examination: Massaging / Foremilking / Foremilking and massaging
24. Udder washed before milking: Yes / No
25. Which udders are washed before milking: From all cows / Dirty udders only
26. Which part off the udder is washed: Whole udder / Teats only
27. The washing water contains disinfectant: Yes / No
28. The udder is dried after washing: No / Yes, with paper towels / Yes, with a cloth
29. Cows leak milk before milking: Yes / No
30. Order in which mastitic cows are milked: First / Last / No specific order
31. Mastitic milk is collected into a separate bucket: Yes / No
32. Have a written Milking Routine: Yes / No
33. Training Frequency: Never/ At Hiring/ Sometimes / Frequently
34. Complete milking routine: Yes / No
35. Predip: Yes / No
36. Forestrip practiced: Yes / No
37. Post-milking teat dipping practiced: Yes / No
38. Iodine product is used to PMTD: Concentrated / Deluded / Don’t used
39. Use California mastitis test (CMT): Yes / No
40. Duration of CMT use: 1 year / 2–3 years / > 4 years / Don’t used
41. Wear gloves: Always / Occasional / Never

42. Milk is filtered before depositing in churns: Yes / No
43. Material of the filter: Metal / Plastic / Cloth or nylon / Plastic and cloth or nylon

**IV. Animal cleanliness:**

44. Cows restrained during milking: Yes / No
45. Source of water used to clean and feed the cows: Potable / Rain water / Irrigation ditch / Water well
46. Cow restrainers are washed: Once a day / Only when dirty / Not washed / Just with brush
47. Cow tail management: Clip tails > once a year / Clip tails > once a year / Tails ringed, cut
48. Average cow dirtiness score: 1.0 / 1.5 / 2.0 / 2.5 / 3.0 / 3.5 / 4.0

1.0 Clean skin and hair
1.5 Mainly clean, some loose manure
2.0 Approximately 50% of area being scored is clean, some loose manure, hair visible through manure
2.5 More than 50% of area being scored is soiled, some matting of hair
3.0 Most of the area being scored is dirty, much of the hair is matted
3.5 All of the area being scored is dirty, most of the hair is matted, little hair visible
4.0 All of area being scored is matted, hair not visible
(Source: O'Driscoll et al, 2008)

**IV. Feeding:**

49. Detail what is the average diet used to feed your lactating cows (kg./cow/day)

Forage kg/cow/day (Green Matter)

Concentrate kg/cow/day

**ANNEX 4:** Questionnaire for commercial dairy processors who have bought a MasterEco

Name of the company: Location:

Name of the responsible: Date:

**I. PRODUCTION:**

With how many farmers do you work? From where?

How many kilograms of milk do you collect from farmers per day?

Do you work with milk collectors?. If is YES with how many?. And how many kilograms of milk do you buy from them?. Do you know where the milk from the collector comes from?

What types of dairy products do you produce?

**II. QUALITY:**

What means milk quality for you?

Which milk characteristics do you think have a main impact at the moment to process your products?. Do you know the exact impact of that component in your products?. If is YES, how do you evaluate that relationship?

What sort of constraints and problems do you face regarding these characteristics at the moment?

What are the reasons for why do you think it is important to check milk quality and dairy products quality through the processing chain?

How is the control of milk quality from farm gate to your dairy outputs in your case?

Do you have any “specification” in terms of quality? YES or NO. If is YES, how often do you check it?

| Parameter | AT FARM LEVEL | | | TO MILK COLLECTOR | | | AT PLANT GATE | | |
|---|---|---|---|---|---|---|---|---|---|
| | YES / NO | How often | Minimum value | YES / NO | How often | Minimum value | YES / NO | How often | Minimum value |
| Acidity | | | | | | | | | |
| Density | | | | | | | | | |
| Fat content | | | | | | | | | |
| Protein content | | | | | | | | | |
| Other 1: | | | | | | | | | |
| Other 2: | | | | | | | | | |

What happens if a farmer or collector does not achieve the required quality?

**III. MILK ANALYZER**

How did you learn about the existence of the milk analyzer?

Why and when did you buy the milk analyzer?

What benefits the seller indicated that you will achieve at the moment he offers to you the milk analyzer?

Does the seller provide any type of service to you (training in the use, data processing, maintenance)?

What characteristics and functions do you think were determinant for you in order to buy the milk analyzer?

How do you use the milk analyzer? Do you analyze milk from all the farmers or only the bulk tank? Do you analyze milk from collectors as well? The analysis is face to face with them or inside the plant gate?

Which parameters from the list of physicochemical components provided by the milk analyzer (Fat, protein, solids not fat, lactose, density, salts, freezing point or water) do you use to accept or reject the milk? Do you have minimum values for them?. If is YES, how did you determine them?

How often do you use the milk analyzer?

Do you keep milk quality records with you? If is YES, how do you process that information?

Did you notice a change in the quality of the milk delivered by your milk suppliers since the use of the milk analyzer?

The use of the milk analyzer in your plant have influenced in the way how you select your milk suppliers now? Did you have changed from milk suppliers since the introduction of your milk analyzer?

Did you perceive a negative reaction from your milk suppliers against the analysis you started to perform with the milk analyzer? Have you observed any difference of reaction between them (e.g. between individual farmers and collectors)?

If you are supplied by collectors, how do they use the quality data provided by the milk analyzer in their relationship with the individual farmers whom they collect milk?

**IV. PAYMENT SYSTEM**

What kind of agreement do you have with your milk supplier (farmers and milk collectors)?. Written contract / oral / other. Under what conditions?

How milk is paid to your supplier? Do you give a bonus or an extra payment to the suppliers according to the quality of their milk?. YES or NO. If is YES, which parameters are considered for a bonus and how are they graded?. If is NO, would you be interested in adopting this measure to ensure an adequate supply of milk quality? How?

To whom do you sell your products?

What kind of agreement do you have with your customers?. Written contract / oral / other. Under what conditions?

How is the payment system with your costumers?

Do you label your products? If is YES, do you provide any information related to milk quality to your customers?

Do you think your customers would be willing to pay an extra for a product which ensures is based with a good milk quality?. If is YES how much?.

**Abstract**
The present study is focused on an analysis of the interaction of the upstream part of the dairy supply chain (farmers and dairies) in the Mantaro Valley (Peruvian central Andes), in order to understand possible constraints both stakeholders face implementing milk quality controls and practices; and evaluate “ex-ante” how different strategies suggested to improve milk quality could affect farmers and processors’ profits. The analysis is based on three complementary field studies conducted between 2012 and 2013. Our work has shown that the presence of a dual supply chain combining both formal and informal markets has a direct impact on dairy production at the technical and organizational levels, affecting small formal dairy processors’ possibilities to implement contracts, including agreements on milk quality standards. The analysis of milk quality management from farms to dairy plants highlighted the poor hygiene in the study area, even when average values of milk composition were usually high. Some husbandry practices evaluated at farm level demonstrated cost effectiveness and a big impact on hygienic quality; however, regular application of these practices was limited, since small-scale farmers do not receive a bonus for producing hygienic milk. On the basis of these two results, we co-designed with formal small-scale dairy processors a simulation tool to show prospective scenarios, in which they could select their best product portfolio but also design milk payment systems to reward farmers’ with high milk quality performances. This type of approach allowed dairy processors to realize the importance of including milk quality management in their collection and manufacturing processes, especially in a context of high competition for milk supply. We concluded that the improvement of milk quality in a smallholder farming context requires a more coordinated effort among stakeholders. Successful implementation of strategies will depend on the willingness of small-scale dairy processors to reward farmers producing high milk quality; but also on the support from the State to provide incentives to the stakeholders in the formal sector.

**Key words:**
Informal market, supply chain management, dairy processing, husbandry practices, modeling.

**Résumé**

La présente étude se concentre sur l'analyse de l'interaction de la partie amont de la filière laitière (agriculteurs et laiteries) dans la vallée du Mantaro (Andes centrales du Pérou), afin de comprendre les contraintes possibles auxquelles ces deux acteurs sont confrontés pour la mise en œuvre des contrôles et des pratiques de qualité du lait , et d'évaluer "ex-ante" comment les différentes stratégies pour améliorer la qualité du lait pourraient affecter les revenus des agriculteurs et des transformateurs. L'analyse est basée sur trois études complémentaires menées sur le terrain entre 2012 et 2013. Notre travail a montré que la présence d’une double filière, combinant les marchés formels et informels, a un impact direct sur la production laitière aux niveaux technique et organisationnel, affectant les possibilités pour les petites laiteries formelles de mettre en place des contrats écrits impliquant des engagements sur la qualité du lait. L'analyse de la gestion de la qualité du lait, des fermes aux transformateurs laitiers, a montré sa mauvaise qualité hygiénique dans la zone d'étude, même quand les valeurs moyennes de la composition du lait sont élevées. Certaines pratiques d’élevage évaluées au niveau de l'exploitation ont démontré leur efficacité économique et leur impact sur la qualité hygiénique. Toutefois, l'application régulière de ces pratiques était limitée, puisque les petits agriculteurs ne reçoivent pas de prime pour un lait de meilleure qualité. Sur la base de ces deux résultats, nous avons co-construit avec des petits transformateurs laitiers formels un outil de simulation pour montrer des scénarios prospectifs, où ils pouvaient choisir leur meilleur produit, mais également concevoir des systèmes de paiement du lait pour récompenser les agriculteurs pour la qualité de leur lait. Ce type d'approche a permis aux transformateurs laitiers de comprendre l'importance d'inclure cette gestion de qualité dans leur processus de collecte et de fabrication, en particulier dans un contexte de forte concurrence pour l'approvisionnement en lait. Nous concluons que l'amélioration de la qualité de petits agriculteurs exige un travail plus coordonné entre les différentes parties prenantes. Une telle mise en place de stratégies dépendra de la volonté des petits transformateurs laitiers de récompenser les agriculteurs qui produisent un lait de haute qualité, mais aussi du soutien de l'Etat aux parties prenantes du secteur formel.

**Mots-clés**
Marché informel, gestion de la chaine d’approvisionnement, transformation du lait, pratiques d'élevage, modélisation.