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Technological progress and productivity in the Quinoa sector

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by:

Juan Cristóbal Birbuet
Carlos Gustavo Machicado

August 2009

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TECHNOLOGICAL PROGRESS AND PRODUCTIVITY IN THE QUINOA SECTOR[♦]

Juan Cristóbal Birbuet[♦]
Carlos Gustavo Machicado[♦]

August 2009

Abstract

The main objective of this case study is to analyze the effect that a significant technological innovation in quinoa processing has had on the productivity of companies devoted to this activity and the impact of such an innovation on the growth and organization of the quinoa cluster in Bolivia, and its possible effects on the future. The study will explain how the boost engendered by technological innovation in quinoa processing has triggered a series of events that have allowed the establishment of an ambitious development program. The sector's main companies and producer associations are part of this program, which is called the "Quinoa Alliance." The program has become a unique opportunity for agro-industrial development in the Bolivian Altiplano, so far characterized by subsistence agriculture.

Keywords: Quinoa, saponin, unit operation, specific consumption, productivity.

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1 INTRODUCTION

This paper shows the role played by a significant technological innovation in the productivity of Bolivian companies dedicated to quinoa grain processing. It also shows how this technological innovation has favored the sector's growth and the creation and consolidation of an ambitious development program in which the principle quinoa processing companies, producer associations and technology developers are all participants. Thanks to the results achieved by this program, which is called the "Quinoa Alliance," the program has gained in strength over the last three years. This has allowed the Alliance to make a development proposal for the sector based on the technological change instigated in all links of the productive chain. This proposal, promoted by the private sector, was welcomed by the Bolivian Government for its soundness and wide-ranging approach to the development of the Bolivian Altiplano.

In order to establish the context of the study, it has to be said that quinoa is a unique grain in the world because of its excellent nutritional characteristics. It has an important content of high-quality proteins, a perfect balance of amino acids and it does not contain gluten. Due to these characteristics, quinoa is a 'complete' food and in several senses unbeatable. In fact, it is considered to be, by several scientists, the best food in the world, in addition to the fact that it is highly valued by international markets¹. For all these reasons, quinoa was declared to be the Perfect Food for Humanity by UNESCO.

In spite of the exceptional characteristics of this millenarian grain, the world seems to have discovered it only recently, which is why it has been called "the top secret super food."² In recent years, world quinoa demand has risen significantly, something which is unprecedented and has been caused by three fundamental reasons which are, in chronological order: (1) the increasing demand for grains with no gluten content (at present 0.4% of the world population have celiac disease³); (2) the accelerated growth in demand of high-quality organic products together with the increase in the fair trade products market; and (3) food efficiency programs

¹ Recently, the NASA's Controlled Ecological Life Support System (CELSS) program has chosen quinoa as their most promising crop candidate, due to its nutritional properties and plant growth characteristics. (The CELSS concept will utilize plants to remove carbon dioxide from the atmosphere and generate food, oxygen, and water for the crews of long-term human space missions.)

² Matt Goulding in an article from *Men's Health* magazine.

³ Celiac disease is a disorder resulting from an immune system reaction to gluten, a protein found in wheat and related grains, and present in many foods, resulting in diminished nutrient absorption in the body.

which are being adopted by several countries with the support of the Food and Agriculture Organization of the United Nations (FAO).

Even though the demand in quinoa is increasing rapidly, the sector's supply capacity is very limited. Bolivia is one of the main quinoa agricultural producers in the world as well as the only producer of the most appreciated variety, "quinoa *real*." However, the annual agricultural production of quinoa *real* is no more than 22,000 tons and this has remained quite constant for the last ten years⁴.

The quinoa productive chain has three fundamental links: (i) agricultural production of the grain, (ii) grain processing and (iii) production of added value products. Until three years ago, the sector's main problem had been located in the second link of the productive chain, grain processing. In fact, the installed processing capacity of companies dedicated to this activity was significantly reduced and the processing technology used had low efficiency rates.

Until the end of 2005, Bolivia's installed quinoa-processing capacity was approximately 5,000 tons per year. That implied that there was only around 35% grain processing capacity available per year. In addition, quinoa-processing companies had high quantities of product loss and the "saponin," a sub-product of great commercial value, was not being recovered. Nevertheless, during the past few years, the quinoa cluster has experienced great progress in processing the grain, the second link of the productive chain. In effect, a revolutionary technological change has been adopted by six of the twelve most important companies in the sector which, jointly, are responsible of 80% of quinoa exports in Bolivia. In three years, these six companies have increased their processing capacity by 550%, simultaneously improving their productivity indicators.

The boost engendered by technological innovation in quinoa processing has triggered a series of events that have allowed the establishment of an ambitious development program. The sector's main companies and producer associations are part of this program, the aforementioned "Quinoa Alliance." The program has become a unique opportunity for agro-industrial development in the Bolivian Altiplano, so far characterized by subsistence agriculture.

To date, critically important steps have been taken in quinoa grain processing and the previous bottleneck in low processing capacity has been surpassed. The next step consists of

⁴ In addition, around 8,000 tones of other quinoa varieties are also produced.

building technological advances for agricultural production of quinoa. Currently new cultivation techniques have been developed and the first prototypes have been implemented and tested. This implementation will come into operation in September 2009 with the first agricultural model unit to be established in the Altiplano. Quinoa Alliance expects to amplify the application of these techniques throughout the entire Altiplano and thereby to achieve a green revolution (see section 7).

The case study is organized in eight sections. SECTION 1 introduces the study. SECTION 2 describes the relationship between the technological innovation that have taken place in the quinoa-processing link of the quinoa productive chain and the creation of the Quinoa Alliance. SECTION 3 presents the results of the mentioned technological innovation in statistical figures. SECTION 4 refers to the process of diffusion of the new technology. SECTION 5 analyzes other elements, apart from the technological, that might affect the productivity of companies. SECTION 6 explores the policies that were applied to promote the quinoa cluster in Bolivia. SECTION 7 describes the importance of focusing the Quinoa Alliance efforts on quinoa agricultural production, and explains the effect that the recent technological advances can have on this link in the quinoa productive chain. Finally, SECTION 8 presents the conclusions of the study.

2 NEW PROCESSING TECHNOLOGY AND THE CREATION OF THE QUINOA ALLIANCE

During the period 2001-2004, the Center for the Promotion of Sustainable Technologies (CPTS), a non-profit organization dedicated to helping industries meet challenges related to sustainable development, carried out Cleaner Production (CP) assessments in five main quinoa-processing companies. These CP assessments were the basis for approaching a more ambitious project --the development of new technology for quinoa processing-- which established the foundations for the Quinoa Alliance's formation.

Until the end of 2004, the CPTS had technically assisted companies from diverse sectors, but it had not designed or constructed any technology. The technical assistance aimed at optimizing processes, so as to reduce the specific consumption⁵ of materials, decreasing, simultaneously, the discharge of pollutants. Such goals were accomplished by the

⁵ The specific consumption is an indicator that expresses the amount of a material consumed per unit of production.

implementation of **best practices**, the improvement of the existing technology or, in some cases, the substitution of equipment with more efficient alternatives available in the market. Nevertheless, the quinoa processing companies' situation required special treatment. The technology being used was highly inefficient and there was no better technology yet available at the market.

The major machinery and equipment manufacturers of the world did not produce custom technology for quinoa processing activity, and therefore this unique segment remained unattended. This arises from the fact that quinoa production is quite small in comparison to other grains. As a result, there are not many companies in the world dedicated to quinoa processing, and the market for specific technology for this sector is comparatively reduced⁶. It is most likely that the major technology manufacturers of the United States, Europe and Japan were not interested in investing R&D resources in a sector constituted by so few costumers. Logically, they focused their efforts in developing technologies for processing the most widely grown and used grains, such as rice, wheat or soy.

In view of that situation, the quinoa processing industries had to use adapted technology originally developed for wheat or rice processing, making use of different production parameters and production scales. The technological adaptation under such conditions caused problems related to processing capacity and efficiency.

Without appropriate production factors, and the lack of a specific combination of them, the quinoa sector had deficiencies in increasing its processing capacity and adding value to the product under competitive conditions. There was, consequently, a huge necessity for better production technology, locally developed, efficient, adequate to the needs and particular characteristics of the sector, and economically accessible to all quinoa-processing companies.

Problems detected in the quinoa sector can be seen in other Bolivian agricultural sectors; for instance, the production and processing of annatto, Brazil nut, tarwi, *cañagua*, sesame and amaranth. All of these products have great potential for growth and insertion into national and international markets. Therefore, we believe that the experience that is reported below is replicable in other Bolivian economic sectors.

⁶ Quinoa crops are limited to certain countries which sustain distinct, particular ecosystems.

Thus, how did CPTS decide to face up to a process of technological innovation? It was not indeed something planned, at least not at the beginning. As mentioned before, between 2001 and 2004, CPTS carried out CP assessments in five quinoa-processing companies (two in 2001, another two in 2003 and one in 2004). These companies were leaders in the sector and had a common feature: they used highly inefficient production technology originally design to process grains with different characteristics. It is probable that CPTS found its motivation to take on a process of technological innovation from the first CP assessment carried out on a quinoa-processing company in March 2001. The company considered that its main challenge was the increase of its processing capability in order to satisfy a growing market. The bottleneck was, in effect, the dry processing of quinoa grain, a step in the process aimed at eliminating impurities and reducing the content of saponins⁷ by scarification.

Quinoa scarification was carried out in a peeler originally manufactured for rice scarification⁸. In such equipment, saponins were removed through friction, rubbing the quinoa grains against a metallic net. As the operation was slow, CPTS tried, during the respective CP assessment, to find the maximum flow of quinoa possible that could be processed without diminishing the quality of scarification. After carrying out several trials with different quinoa scarification flows, it was discovered that scarification quality improved as the quinoa flow entering the scarifier increased. These results revealed that scarification was accomplished not by rubbing the grains against the metallic net but by the friction generated between the grains themselves; the quinoa grains had, indeed, inherent abrasive properties. The metallic net was, therefore, absolutely unnecessary in addition to the fact that it damaged the grain, causing product losses. It was definitely an operation that used inappropriate equipment. This motivated a deeper rethinking of the technology.

After the CP assessments in the other quinoa-processing companies, where CPTS also evaluated the characteristics of the technology used, the necessity to embark on the development of new technology became more evident. The problems identified in the quinoa-processing companies can be summarized as follows:

⁷ Saponins, which are coating the grain, need to be removed as they confer a bitter taste to the grain. Nevertheless, saponins constitute a sub-product of high commercial value because of its fungicidal applications.

⁸ Other companies used fruit pulpers, sorghum peelers, etc.

- Significant losses of raw material (grain), with the consequent increment in the quantity of residues discharged.
- Low quality of the grain.
- High specific consumptions of water, electrical energy and gas, with the consequent increment in production costs.
- Intensive use of labor force, with the consequent increase in operation costs.
- Wastewater with high contents of saponins, with the consequent pollution of bodies of water.
- Unfeasibility of recovering pure saponin, with the consequent loss of its commercial value.

The main *causes* of these problems and the respective technological solutions that were proposed are as follows.

- a) *Use of adapted technology in an inadequate manner for processing quinoa.* For instance, the use of rice peelers for the scarification of quinoa. This caused not only product losses, but also a loss of grain quality. To solve the problem, an efficient system of dry cleaning was designed, constructed and implemented. The system used the inherent abrasive properties of quinoa for scarification, through friction between grains. In addition, a system of saponins recovery was installed in order to recuperate this important sub-product that was previously being wasted.
- b) *Washing systems with a wide range of residence time.* Quinoa-processing companies used washers with turbulent flows in order to accelerate the washing process and eliminate the saponin remaining on the grain. When water flow is turbulent, quinoa grains exit the washer randomly; that is, the last grain entering the washer can be the first to come out, or the first one entering can be the last to come out. This produces two negative effects: (i) in the case of a short residence time in the washer, grains come out badly washed and must be re-washed, consequently increasing operation costs; (ii) in contrast, with a long residence time, the grains are excessively moistened as well as increasing their processing time, energy costs for drying, and reducing product quality due to the dissolution of salts, proteins and starches in the washing water.

To arrive at the solution for this problem resulted in one of the most important innovations: the design of a washer which accomplishes the simulation of a laminar trajectory of the grain,

through the use of a turbulent flow. This guarantees that the first grain entering the washer is the first one exiting. In addition, the system reduced the average time of residence in the washer, from 22 minutes to 4.7 minutes. The efficiency variant between the old and the new washing systems is illustrated in Figure 1.

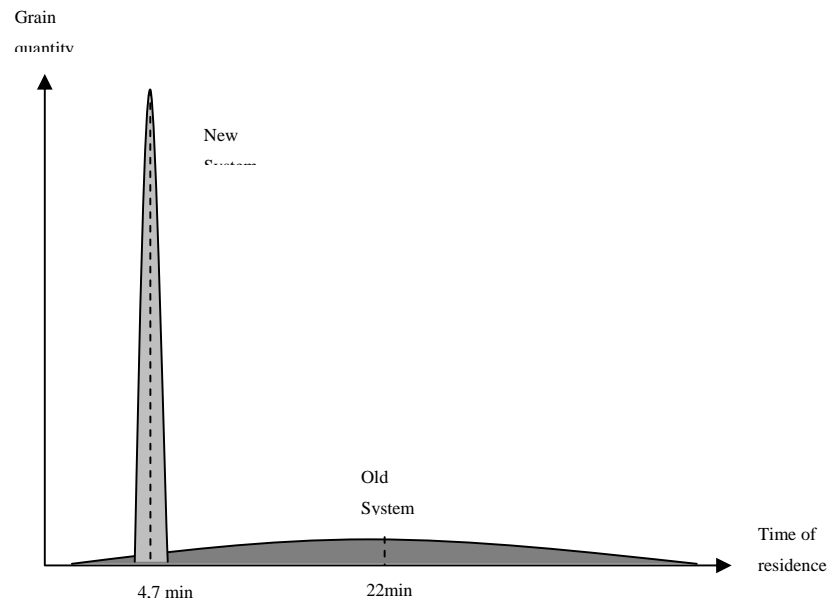


Figure 1 Optimization of the quinoa washing time with the new system

Source: CPTS

- c) *Drying systems with insufficient air flows, which allowed the re-humidification of the grain in a significant percentage.* The new drying system design is highly efficient. It employs a turbine which generates a greater air flow with lower energy consumption. The efficiency of the turbine is 76%, almost double that of similar turbines manufactured in other countries⁹.
- d) *Use of technology that did not allow the recovery of sub-products of high commercial value.* For instance, saponin, which has a high economic value in the market. Using older technology, saponin was contaminated with impurities from the quinoa and particles detached from the grain itself. As a result, the price of saponin decreased by 70%. Moreover, in various cases, saponin recovery was not at all possible.
- e) *Use of technology that operated in small batches (not **in-line**, or , not continuously).* For instance, the centrifugation operation was carried out in batches of less than 20 kg and

⁹ The turbine has been patented by CPTS.

demanded an intensive labor force with exclusive dedication. The new technology operates in a continuous manner and demands few personnel.

f) *Excessive, and in some cases, unnecessary number of unit operations in the process, with the consequent use of an excessive number of machines associated with each of the unit operations.* For example, after the washed grain drying and centrifugation process, which takes into account a previous destoning system, and in spite of the existence of a prior, initial dry cleaning operation, the grain was cleaned again using various machines including additional destoners, venting machines, an optical colored particles selection system and, finally, a manual impurities selection system carried out by personnel exclusively dedicated to this purpose. The new technology is more efficient in each of the steps in the drying and wetting process; for this reason, there is no need to include additional cleaning unit operations after these processing steps have been concluded.

The only means of solving these detected problems was, clearly, to develop a more efficient overall technology. The old technology was so inefficient that nothing from it was taken into account to design the new one.

In 2005, the United States Agency for International Development (USAID) granted funds for the execution of a demonstration project aimed at designing and constructing an entire quinoa processing plant, based on Cleaner Production (CP) principles and adapted to the needs of the **existing** quinoa processing companies. The technology was designed by CPTS, constructed by Industrias Metálicas Andinas (IMA) and installed at Andean Valley SA (AVSA).

In 2006, the first prototype of the new technology began working and increased AVSA's processing capacity from 240 tons/year to 1,900 tons/year. In addition, this technology considerably reduced AVSA's operation costs, which resulted in increased cash flow and the improvement of its environmental performance indicators. The success achieved with the implementation of the new technology led to the establishment of an alliance between CPTS, IMA and AVSA. The alliance aimed initially at consolidating the work relationship that arose between these companies during the prototype development phase. In the long term, the purpose has been to focus the joint effort in research and development activities within the quinoa sector.

As soon as the dissemination of the technology began, other companies and institutions joined the alliance, which finally resulted in the establishment of the formal 'Quinoa Alliance.' To join the Quinoa Alliance, enterprises must establish very well defined investment

commitments. In the past two years, the member companies have invested more than US\$3 million in new physical infrastructure, new machinery, and training for its suppliers, among others.

At the end of 2007, the installed capacity for the industrial processing of quinoa in Bolivia grew from 5,000 tons/year to 18,700 tons/year (see Figure 2). The increased, installed capacity allows, at present, the industrial processing of about 85% of total quinoa production. However, the 15% gap between processing capacity and agricultural production does not imply that there is still the possibility for an increase in processing capacity. In fact, not all quinoa grain can be industrially processed, since farmers self-consumption represents a portion of quinoa cultivation, and another portion is used by them as seed for the following agricultural year. There is also a substantial quantity of quinoa illegally shipped to Peru. Thus, with the current installed capacity, the companies are already experiencing difficulties in purchasing quinoa for processing (raw grain). This deficit in agricultural production caused a price increase for raw grain from US\$ 740/ton in January 2007 to US\$ 2,300/ton in June 2008. This price increase of 308% in a year and a half has no precedent and is greater than those registered in other foods during the same period. Clearly, at least part of the price increase is due to the greater demand for the quinoa grain caused by the increase in processing capacity within the sector.

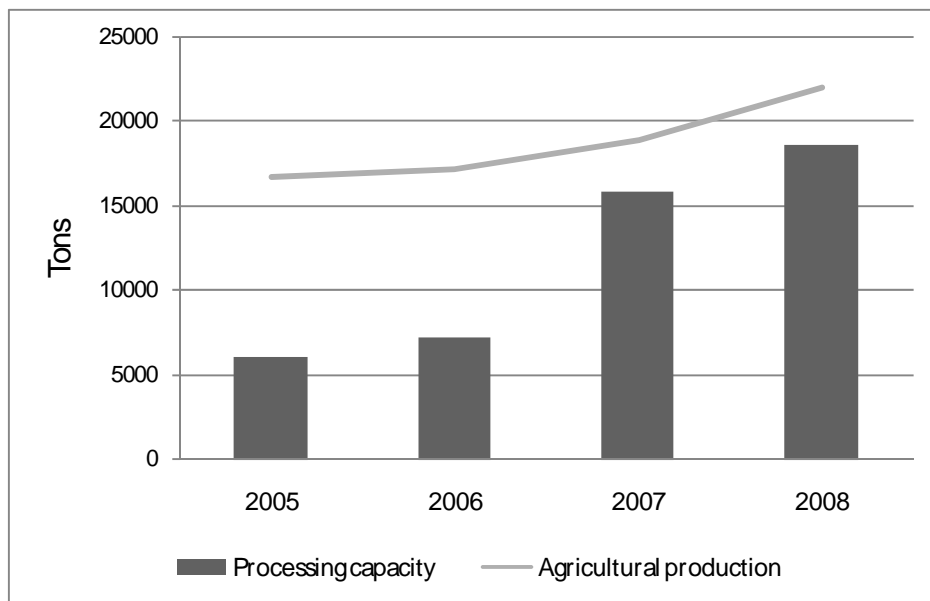


Figure 2 Quinoa agricultural production and internal processing capacity trends

Source: CPTS and National Institute of Statistics (INE, in Spanish)

Considering that the current processing capacity of the new production lines (using new technology) is 2,800 tons per year, 100% of quinoa production could be processed with the installation of one additional production line. With the current orders for processing lines or technology, the global processing capacity could rise to 32,700 tons in a few months; that is, the installed capacity could then exceed the agricultural production of quinoa real by approximately 50%. For that reason, the sector's companies, even those that do not have new technology yet installed, consider that the processing capacity problem has been solved to a large extent. At present, the technology supplier (IMA) can manufacture, in an average of a month's time, a complete new-style processing line with the capacity to process an annual production of 5,600 hectares of quinoa (given the current crop yield)¹⁰. This implies that, very quickly, Bolivia could have an installed processing capacity greater than its agricultural production, which could result in a severe negative impact on soil sustainability.

In view of that negative potential, the members of the Quinoa Alliance have defined a policy aimed at increasing the installed processing capacity concurrently with a sustainable augmentation of agricultural production. This can be accomplished by changing agriculture's technological matrix in the Bolivian Altiplano. Recent research and trials carried out in the field show that it is possible not only to increase crop yield significantly, but also to enlarge the agricultural boundary of the Altiplano in a sustainable manner, using lands that, for decades, were considered unsuitable for agriculture. In fact, these lands have resulted in being the best for quinoa cultivation. Quinoa sector development represents, today, a unique opportunity for progress for all families in the poorest region of the country: the Altiplano.

As mentioned above, the Quinoa Alliance includes, at present, six main companies from the sector, which jointly are responsible for 80% of quinoa exports in the country. The purpose of the Alliance is to promote a comprehensive development of the sector on the basis of technological innovation. In order to achieve this, a clear and ambitious objective has been proposed: to increase the agricultural production of quinoa real from 22,000 tons per year to 1,000,000 tons per year in 15 years. Such a proposal, made by the private sector, has been supported by all members of the Alliance and well received by the Government, which has

¹⁰ At present, crop yields are around 500 kg of quinoa per hectare and the cultivated area of quinoa real is approximately 46,000 hectares.

included the quinoa cluster among those strategic sectors that must be supported in the framework of a productive development plan.

At the moment, the Ministry for Rural Development, Agriculture and Environment¹¹ and the Ministry for Development Planning¹² strongly believe that Government intervention must be closely linked with the proposal of the Quinoa Alliance.

3 TECHNOLOGICAL DEVELOPMENT IN FIGURES

The increase of the quinoa-processing installed technology capacity

As previously mentioned, until three years ago, the main bottleneck for the quinoa cluster had been the reduced processing capacity of the companies. At present, the installed capacity allows the processing of nearly all agricultural production of quinoa with great efficiency.

Table 1 shows the increase in quinoa processing capacity in Bolivia before and after the introduction of the new technology. It can be observed that during the period 2005-2008 the installed capacity, in the six companies that upgraded their processing technology, increased by 550%. This contributed to an increase of 374% in quinoa's global processing capability.

Table 1 Installed processing capacity of quinoa in Bolivia

Company	Installed capacity before technological innovation [tons/year] 2005	Installed capacity after technological innovation [tons/year] 2008	Processing capacity increase [%]
AVSA	240	1,900	792
ANAPQUI	920	2,800	304
CECAOT	440	2,800	636
QUINOABOL	600	2,800	467
IRUPANA	600	2,800	467
CEREALES ANDINA	50	2,800	5,600

¹¹ "Ministerio de Desarrollo Rural, Agropecuario y Medio Ambiente".

¹² "Ministerio de Planificación del Desarrollo".

Installed capacity in the 6 companies	2,850	15,900	550%
Installed capacity in other companies (*)	2,150	2,800	32,5%
Total installed capacity	5,000	18,700	374%

(*) These companies do not have the new technology yet.

Source: CPTS

Thanks to the technological innovations that began in 2006, the companies were in better conditions to satisfy an increasing quinoa demand. During the period 1998-2007 quinoa exports increased by 747% but, it is since 2006 that the slope of the exports curve has increased significantly (see Figure 3). Such a significant augmentation in exports coincides with the implementation of the new quinoa processing technology and shows the greater response capability of national companies to the international quinoa demand.

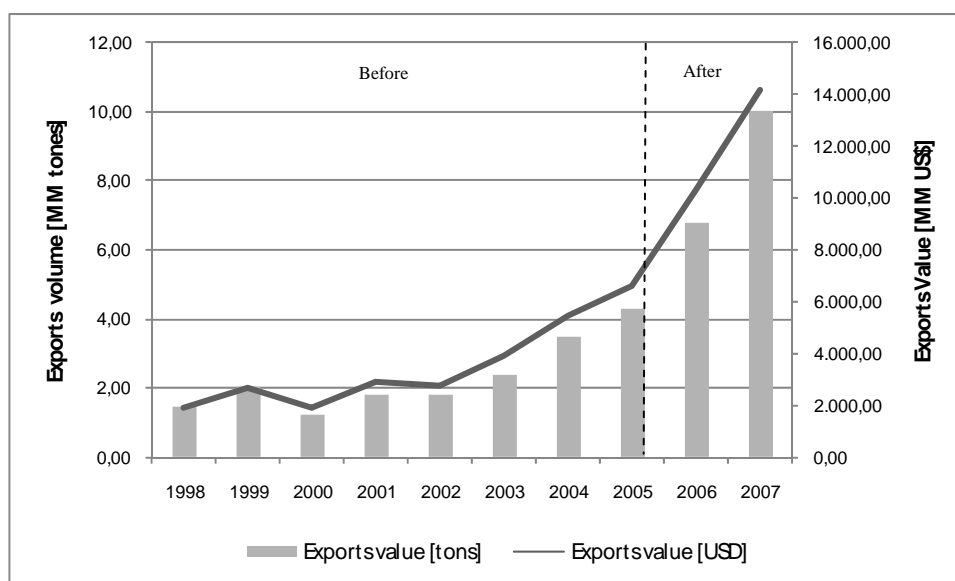


Figure 3 Quinoa exports from 1998 to 2007

Source: CAMEX (Cámara de Exportaciones)

Nowadays quinoa real production represents about 3.6% of agricultural GDP. As shown in Figure 4, its participation has been rising in recent years. In 2007 the agricultural GDP was US\$320 million and its contribution to the national GDP was 17%.

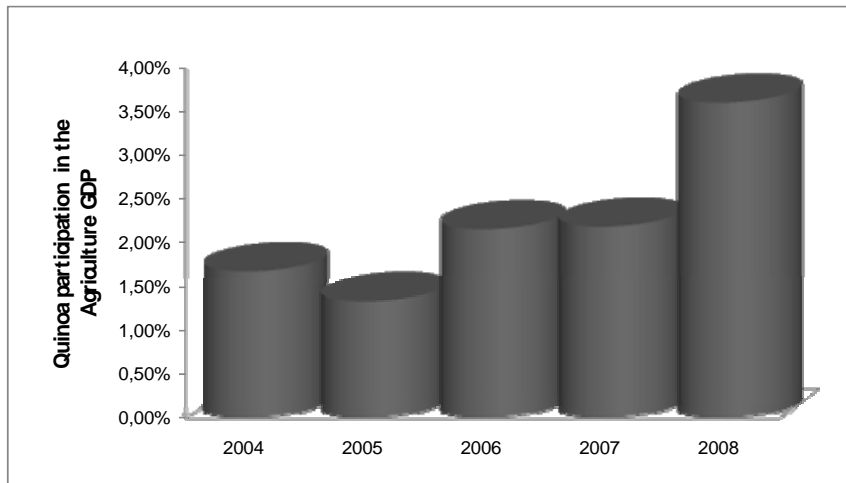


Figure 4 Quinoa Participation in the agriculture GDP

Source: INE and CPTS.

As important as augmentation of the processing capacity of companies and their greater response capability to the increasing quinoa demand have been, so too have the increase of both input use efficiency and production factors efficiency. This was indeed a consequence of the implementation of a technology specifically designed for quinoa processing under the criteria of Cleaner Production (CP). In effect, the new technology resulted in greater economic and environmental benefits for these companies.

Increase of productivity and convergence

In order to illustrate the impact of the application of the new technology on productivity, various tests and measures were carried out in 3 representative companies which are responsible for 47% of quinoa exports (IRUPANA, AVSA and ANAPQUI). Seven productivity indicators were used: (i) electric energy-specific consumption, (ii) water-specific consumption, (iii) thermal energy-specific consumption, (iv) percentage of saponin recovery, (v) global yield, (vi) efficiency of labor force use, and (vii) efficiency of capital use. These indicators made possible the comparison of efficiency levels before and after the implementation of the new technology.

Two main sources of information were the basis for the calculation of the first five indicators mentioned above: (i) material and energy balances and (ii) material and energy consumption records. The material and energy balances helped in identifying the materials and energy that are consumed exclusively in quinoa grain processing. This was needed for four fundamental reasons. First, because some companies process not only quinoa but other foods

which also demand both energy and materials resources. Second, because companies, aside from their respective grain processing, add value to the grain (e.g., flour, flakes and pop quinoa). Third, is the fact that various companies do not systematically register their consumption of certain materials or energy. And fourth, because some companies do not keep records of grain processing yields.

The information employed to calculate the efficiency of labor force use is related to the number of employees working exclusively on the grain processing line. We record the number of daily hours worked by these employees *before* and *after* the implementation of the new technology as well as the number of working days per year within each company. This information was gathered using the CP assessments and follow-up reports. In some cases, the companies were asked to complete previously missing information.

Finally, the data used for the calculation of the indicator of the efficiency of capital use was the book value of machines and equipment, which has been provided by the companies. In contrast to the total value of fixed assets, the information related to the book value of machines and equipment allows us to specifically determine and highlight the changes in productivity associated with the implementation of the new technology. These changes in productivity are not clearly related to other assets. Moreover, some companies use assets such as land, buildings, vehicles, computers, etc., to support quinoa processing as well as the processing of other foods and therefore the attribution of use of this type of asset only for quinoa production is extremely difficult. That is why these assets were not taken into account.

Table 2 shows the productivity indicators before and after the implementation of the new technology at IRUPANA, AVSA and ANAPQUI. Definitively and without exception, the technological innovation improved all productivity indicators in the 3 companies.

Table 2 Productivity indicators

Productivity indicators	IRUPANA		AVSA		ANAPQUI	
	Before	After	Before	After	Before	After
Electricity specific consumption [kWh/ ton of processed grain]	58.26	32.8	94.7	44.7	78.2	42.1
Water specific consumption [m ³ / ton of processed grain]	12.8	8.65	14.0	6.0	9.7	4.5

Thermal energy specific consumption [Mcal/ ton of processed grain]	505	113	354	104	177	114
Saponins recovery [ton of saponin/ ton of raw grain]	0.0	0.045	0.0	0.039	0.0	0.052
Global yield [tons of processed grain/ ton of raw grain]	0.835	0.901	0.918	0.936	0.785	0.902
Labor force use [man-hours/ ton of processed grain]	160.0	44.4	180.0	39.6	277.0	47.0
Capital use [US\$ of machinery and equipment/ ton of processed grain]	184.0	75.3	215.7	150.0	418.1	204.4

Source: IRUPANA, AVSA, ANAPQUI and CPTS

It is worth highlighting that the increase in productivity evolved simultaneously with a convergence process of the productivity indicators (see Table 3). The reasons for such a convergence are: (i) the substitution of batch operations by a continuous process, and (ii) the exhaustive technical training provided to the employees at the time the new technology was installed. This training allowed the “homogenization” of the operations management through procedures using parameters control and the establishment of production protocols. Before, no norms or procedures were followed.

The standard deviation is used as a dispersion measure of the inter-company productivity. Table 3 shows its value before and after the technological change¹³. With the exception of the water specific consumption indicator, all productivity indicators show a lower inter-company standard deviation after the implementation of the new technology. This signifies a greater convergence in the productivity of the sector.

¹³ The dispersion measure was applied to all productivity indicators with the exception of the one related to the recovery of saponin because saponin was not recovered before the implementation of the new technology.

Table 3 Convergence of productivity indicators

Productivity indicators	Inter-company Standard Deviation before the new technology	Inter-company Standard Deviation After the new technology
Electricity specific consumption [kWh/ ton of processed grain]	14.9	6.3
Water specific consumption [m ³ / ton of processed grain] (*)	1.8	2.1
Thermal energy specific consumption [Mcal/ ton of processed grain]	133.8	5.8
Global yield [tons of processed grain/ ton of raw grain]	0.05	0.02
Labor force use [man-hours/ ton of processed which grain]	51.1	3.75
Capital use [US\$ of machines and equipment/ ton of processed grain]	103.7	64.8

(*) The increase in the Inter-company Standard Deviation is due to problems in the lay out of the new installations at one of the processing companies.

Source: CPTS

4 THE DIFFUSION OF THE TECHNOLOGY

The demonstrative workshop

The diffusion strategy consisted of a demonstration workshop carried out at AVSA (Andean Valley SA), where the first prototype had been installed. The objective of the workshop was to show the technology in full operation and the benefits implied in terms of: (i) increase in processing capacity, (ii) materials and energy-specific consumption reduction, (iii) recovery of saponin as sub-product, and (v) reduction of pollutant discharges per ton of quinoa processed (specific discharges).

A few weeks after the workshop, four companies placed their formal orders for the purchase of the technology. The only problem was that IMA (Industrias Metálicas Andina, the technology manufacturer) could not construct a complete unit of quinoa processing equipment in less than 8 months and no other manufacturer had the adequate technical capacity to produce precision components. This meant that the last company would receive the technology in 2 years and 8 months. For that reason, IMA reinvested the money earned from the first sale of the technology equipment unit for the expansion of its infrastructure and the hiring and training of new personnel. Today, IMA is the main technology supplier for the quinoa sector and is capable of constructing an entire quinoa processing line in an average time of one month.

The temporary suspension of the technology construction

In 2008, CPTS and IMA suspended temporarily the production of the technology, even if there was still pending orders or demand for this machinery that had not yet been met. In fact it was not viable to construct new quinoa processing units without being able to create the conditions to augment significantly the agricultural production of quinoa in a sustainable manner. This implied an almost exclusive dedication to the development of agricultural technology, keeping active only maintenance services for quinoa processing units that had already been installed. Thanks to economic resources from USAID and the Embassy of Denmark, CPTS and IMA would be able carry out the activities related to research and development of quinoa agricultural technology. Those resources compensated, to a certain extent, for the lost income that was being incurred from the now-suspended sales of the quinoa processing technology.

It is important to underline that, with the already installed units; almost all quinoa agricultural production could be processed. As a result of the lack of sound agricultural technology, several producer communities adopted desperate but not sustainable measures to augment their agricultural production¹⁴. Even if this behavior is comprehensible, taking into account that in the southern part of the Altiplano quinoa agricultural production represents between 50% to 85% of the total income of the producer families¹⁵, and the increase in demand and prices of quinoa were great incentives for the cultivation of this product, it is also true that

¹⁴ Among the inadequate practices adopted by the producers as a result of the lack of sound technology, we can mention the reduction of the soil rest period and the use of inadequate technology (e.g. the use of disc plows).

¹⁵ According to Brenes, Crespo and Madrigal, 2001.

these practices did not result in a significant increase in quinoa agricultural production. To the contrary, these, in fact, reduced the soils productivity and compromised their sustainability in the medium and long-term.

It is worth reiterating here that quinoa agricultural production is about 22,000 tons per year and that each new quinoa processing unit can process around 2,800 tons of quinoa per year. The augmentation of the processing capacity as a result of the technological change was, therefore, exerting an additional pressure on the soils employed traditionally for this crop. Evidently, it was not correct to continue the installation of new processing lines without solving the fundamental agricultural problem. To increase agricultural productivity is indeed the great challenge within the quinoa sector.

5 OTHER ASPECTS THAT INFLUENCE PRODUCTIVITY AMONG QUINOA COMPANIES

In addition to the technological change, other factors can influence the productivity of quinoa processing companies. Some of those factors or elements are mentioned here.

The different types of companies

It is important to analyze the influence which different forms of ownership have on companies' productivity. Accordingly, two types of companies will be differentiated: (i) those in which quinoa producers have ownership rights, which allow them to receive part of the profits (social companies), and (ii) companies in which the quinoa producers do not have any ownership participation; they are only quinoa suppliers (private companies). It has been noted, for example, that the market and the public policies discriminate positively the social companies. Five fundamental aspects differentiate the two types of companies:

1. Social companies have a board of directors, constituted by the quinoa producers, which has defined administrative functions. These companies set control guidelines which are stricter and more complex than those of private companies. To receive the support of associated producers for any decision made, the board must strenuously "socialize" the decision in order for it to be accepted. This can result in decisions not being made on time, which can have negative repercussions in a rapidly changing context. On the contrary, private companies make decisions more rapidly and efficiently.

2. The board in social companies, in contrast to private enterprises, is unstable. The correspondent statutes oblige the board to change its membership every two years. In some cases, board members can remain for one or two additional years, if management has been exceptionally good. Nevertheless, this happens rarely.
3. The use or application of profits in social companies is defined within its statutes. That is the reason why there is little flexibility in determining the best use of those profits. An example of profits distribution in a social company is given here:

25%	Social Fund (for producers' retirement pensions)
10%	Training
10%	Operations capital (raw quinoa purchases)
27.5%	Investment capital
13.75%	Regional organizations
13.75%	Associated producers

4. The academic background of board members and its personnel in social companies is far from optimal. There are in fact better prepared people in private companies. For this reason, management in social companies is less efficient. This has resulted in the loss of market segments which have been garnered by private companies.
5. Social companies, in contrast to private companies, are vertically integrated. Private companies can not include the agricultural link into their value chain by law. The land belongs to the producers or is considered as communitarian, and therefore according to law, these cannot be sold to private companies. In contrast, the producer-members are owners of the social companies as well as the tracts of land, or have the right to use the land because they are part of the given community. In view of that situation, private companies have developed strategies to strengthen their relationships with their suppliers, who are independent producers that are not associated with any of the existing social companies, but have exploitation rights to their lands.

To understand the coexistence that has been established between both types of business organizations it is necessary to take into account social, cultural and economic factors that have taken place since the foundation of these companies. Private companies were endeavors fomented by urban families with an academic background, their structure is formulated by western-oriented business logic, and their main goal is to obtain economic profits and sustained

competitive growth. Social enterprises have been organized in rural areas, developed from within already-established social organizations that have achieved a certain degree of achievements¹⁶, while making use of established communitarian organizational and decision-making logic. Peasants were organized into social enterprises so as to provide for economic needs that could not be fully met individually. Also, they grouped together to obtain facilities, services and assets that are inherently too expensive for each individual associate alone.

Collective work means building a social subject from which to organize the work and to make decisions on how, when and how much to produce, as well as income and profits distribution. It means identifying common interests and common objectives that can be achieved through joint ventures; and to move from an individual decision-making stance to a collective one, which limits the individual's freedom in the decision-making process, superimposing instead the common welfare. Therefore, initial objectives of social enterprises were not simply proposed in terms of profitability and competitiveness, as they are with private companies; but, from their outset, assumed far more extensive and ambitious objectives relating to collective welfare, mutual aid, cooperation, social service, and high turnover of the directive. This has stimulated a high degree of participation within these companies.

Social enterprises reproduce certain principles of correspondence, complementarities, reciprocity and social control, which are typical of Andean communities. It is important to recognize that they move within another form of logic and another type of philosophy, which is also reflected in their distinctive and quite different structure of business organizational.

The fair-trade effect

Some markets tend to favor social companies, with better prices through “fair-trade” practices. Until three years ago, private quinoa-processing companies could not gain access to the fair-trade mechanism. During that time, the market price was approximately US\$1,000 per ton of processed quinoa, while the fair-trade price was about US\$1,500 per ton.

Undeniably, social companies have benefited from this impressive difference in price (50%). However, several private companies consider that during the period that they could not gain access to the fair-trade mechanism, their role with producers was similar to that of social

¹⁶ In general, the organization of social enterprises was supported and influenced by different groups, such as non-governmental organizations and international cooperation agencies.

companies. They also assert that, in most cases, the price they paid directly to individual quinoa producers (farm-gate price¹⁷) was superior to that paid by social companies that benefited from fair-trade.

Fair-trade also created certain distortions within some producer associations because of the typical small-scale transactions which are characteristic of this market. In effect, social companies had to choose which producers were going to benefit from the fair-trade price, since the demand from the fair-trade market was not as large as the total product offered by all of these associated producers. This caused a number of conflicts among social companies, first, because clear mechanisms did not exist for determining which producers were going to be favored with fair-trade prices, and second, because there were a lack of compensation mechanisms (plural) for those producers that could not gain access to the fair-trade price and that demanded a “fair” and similar treatment, considering that they are also associates.

Some time ago, the fair-trade market opened its doors to private companies. Some of these companies began to prepare all the necessary requirements to obtain the respective certification. However, with the increase in the quinoa grain price, in 2008, the fair-trade market was no longer attractive. According to several companies, the fair-trade incentives disappeared when processed quinoa exceeded the value of US\$1,600 per ton. Ironically, when this occurred, the respective negotiations for price increases were more difficult with the “fair clients” than with “normal clients”.

Figure 5 shows the increase of quinoa farm-gate and FOB prices during the period 2007-2008. As observed, the farm-gate price reached the value of US\$2,300 per ton, and the FOB price, US\$3,100 per ton, almost double what the fair trade had paid a year before. In March and April 2008, the farm-gate and FOB prices were practically the same. However, since May of that year, Bolivian quinoa companies negotiated other prices with their international clients. Currently, the difference between the farm-gate and FOB prices reached a historic maximum. This implies that the Bolivian companies re-negotiated the price efficiently.

¹⁷ Term used in fair trade to indicate the price paid to the producer.

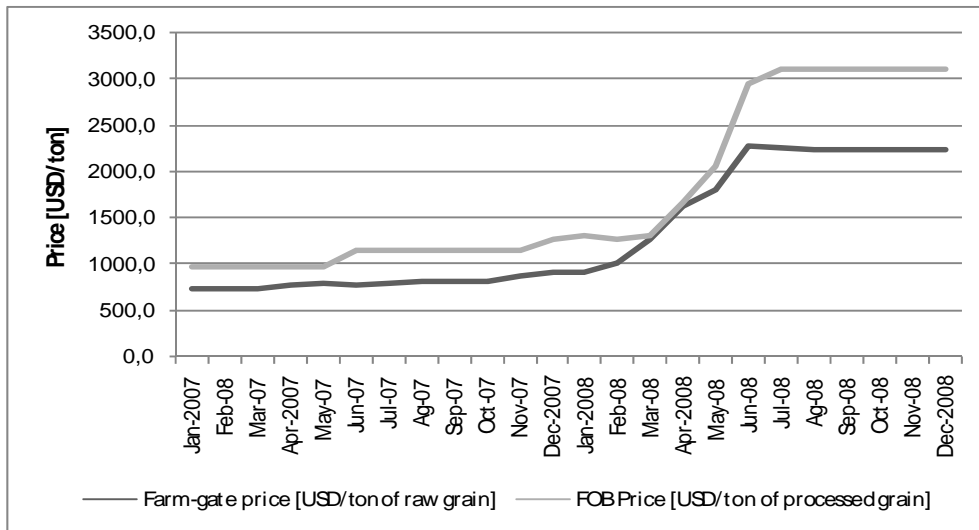


Figure 5 Farm-gate and FOB prices of quinoa from 2007 to 2008

Source: Member companies of the Quinoa Alliance

Asymmetry of information 1: Which is the most convenient color?

If the quinoa grain was to be valued only for its nutritional properties, its color (appearance) would not be of importance. However, the farm-gate price varies according to the color of the grain.

There are three colors of quinoa *real* grain: white, red and black. The most known and abundant variety is white quinoa. In European and US supermarkets the prices of red quinoa and black quinoa are, respectively, 42% and 51% greater than white quinoa. Nevertheless, in Bolivia, the quinoa farm-gate prices are defined in an opposite sense to the preferences of world consumers. In effect, the Bolivian producers offer red and black quinoas at a price 40% lower than the price of white quinoa. The reasons for the establishment of such prices are unknown.

Apparently consumers are willing to pay more for the red and black varieties since these are more *exotic*. The social companies are not aware of this; apparently their international clients did not inform them of those preferences. The social companies pay, therefore, lower prices to their associates for the most appreciated quinoas. They also export it at lower prices.

The private companies, in contrast, are better informed about the preferences of the international market and, for many years, negotiated a higher price when they sold red and black quinoas to their international clients. In 2008, the export prices for white, red and black quinoas were equal as a consequence of the significant increase in the general prices of quinoa, which

made it impossible to charge, in addition, an extra price for the colored varieties. However, as the farm-gate prices for colored varieties are lower than international supermarkets prices, private companies are capable of obtaining a greater margin of profit when they commercialize red and black quinoas.

Asymmetry of information 2: To whom is the quinoa real with organic certification expensive?

According to Bolivian companies, quinoa is a product with an inherently higher price than other products that compete in the organic market. It was then a great surprise when, in 2008, international clients continued to increase their orders even as prices rose. However, in Europe and the USA, quinoa grain is not sold at a higher price to the end-user/consumer than other organic products. At supermarkets, the same retail price is paid for other forms of organic products. For instance, half a kilo of quinoa, half a kilo of beans or half a kilo of lentils are sold at the same price to consumers.

In addition to supplying the international demand, Bolivian quinoa companies pursue the challenge of stimulating broad-based local quinoa consumption. So far, public incentives for internal quinoa consumption have been focused on specific programs, such as school breakfasts or Armed Forces meals. In effect, those policies have not yet achieved massive internal consumption of quinoa. It is important to note that quinoa real prices with organic certification in the domestic market are so high that they are accessible only to a small segment of the population. At present conditions, only second-level quality grain is consumed by the majority of domestic consumers. As will be explained in the following paragraphs, this is mainly due to the policy of fixing prices of certified quinoa in the domestic market.

Comparatively, it is more expensive to eat organic quinoa in Bolivia than in Europe. For instance, a liter and a half of Coca Cola in Europe costs approximately US\$4, and half a kilo of quinoa, US\$4.9. That is, half a kilo of quinoa is 22.5% more expensive than 1.5 L of Coca Cola. In Bolivia, on the contrary, 1.5 L of Coca Cola costs approximately US\$0.85, and half a kilo of quinoa, US\$2.50, that is, 290% more expensive than a bottle of 'Coke.' Evidently, in Bolivia, it has been easier to spread the massive consumption of Coke than of home-grown, organic quinoa.

The amazing difference between the relative prices for quinoa real with organic certification and Coca Cola corresponds primarily to that policy of quinoa companies fixing prices in the domestic market. Currently, there are three companies that offer quinoa real with

organic certification in this market. The conversation we had with one of them offered us some insight into the reasons for the large difference in the relative prices of these two products.

When quinoa companies export their products, they charge the FOB Arica price, i.e., one that results from adding to the Ex-Works price, transport, tariffs and administrative costs for the exportation of goods up to the port of shipment (Arica, Chile). To set the price in the domestic market, it could be assumed that the fixed price procedure consists of adding to the Ex-Works price the cost of fractionation and packing the product into boxes of 500 grams, the costs of distribution, marketing and, finally, the profit margin charged by the retailer (e.g., a supermarket charges approximately 30%). However, instead of doing this, what is actually done is to add to the FOB Arica price all these extra costs. In addition, an extra utility charge of 20% is included. In other words, the price for the domestic market includes costs that should in no way be incorporated. Moreover, onto the profit margin already charged by the companies and included in the Ex-Works price, yet another 20% profit margin is added to the price when the companies commercialize the product in the internal market. This, to a great extent, explains why the certified quinoa real in relative terms is more expensive in Bolivia than in Europe or in the United States.

It is obvious that quinoa real with organic certification is traded in the domestic market only for a sector with high purchase power. Moreover, the quantity sold domestically as grain represents a very small fraction of the country's production and, apparently, it is only part of a commercial strategy that pursues the introduction of value-added products based in quinoa (cookies, corn flakes, pasta, and so forth).

On the other hand, the GDP per capita in Bolivia is US\$3.70/day, while in Europe the average GDP per capita is over US\$100/day. It is then easy to understand why the major part of quinoa real production is exported. The sole approach that can be deployed, to have more quinoa available to the internal market at more accessible prices, is to increase, in a sustainable manner, agricultural production. This indeed requires better technology, well-trained human resources and efficiently organized, proper infrastructure.

6 POLICY CONSIDERATIONS

Coordination among the development actors

The design and application of development policies for any sector require the coordination of different public and private institutions. In the case of the quinoa sector, the role of coordinator was played, at the beginning, by the Competitiveness and Productivity Unit (UPC in Spanish¹⁸), a decentralized institution of the then Ministry for Economic Development, created in November 2001. The UPC focused on strengthening the productive sector through the coordination and consensus of the public, private and academic sectors, suggesting public policies reforms and proposals to achieve productive development¹⁹. The UPC made the first coordinated attempt to formulate public policy for the sector, including the contributions of all the actors involved. The members of the Quinoa Alliance were among them. They participated actively in the design of the intervention plan.

UPC's involvement with the quinoa sector began in 2001, with their identification of priority sectors warranting direct action. The UPC applied a comprehensive approach towards productive chains. It prepared twenty case studies of productive chains and prioritized eight; the quinoa productive chain was one of those selected that were given the high development potential. The next step involved the creation of the Quinoa Competitiveness Committee, which was followed by the signing of the Bolivian Competitiveness Agreement (ABC in Spanish²⁰) by all the actors concerned. The first quinoa ABC was signed in 2002, and the second in 2004. For the first time, public interest in supporting the Bolivian quinoa productive sector was explicitly expressed, identifying all relevant actors. In the beginning, the quinoa productive chain program obtained an economic contribution of US\$4 million provided by the Kingdom of the Netherlands. The central idea was that this donation would serve as the initial capital to leverage State resources in much greater amounts; however, it did not happen.

After the ABC signed in 2004, a working agenda, named the Agenda of Shared Responsibility (ARCO in Spanish²¹), was defined. The Agenda established all activities to be carried out by each of the participants, the respective deadlines and the correspondent

¹⁸ UPC: Unidad de Productividad y Competitividad.

¹⁹ Presently, the UPC is a decentralized unit within the Ministry of Development Planning, created in 2006.

²⁰ ABC: Acuerdo Boliviano de Competitividad.

²¹ ARCO: Agenda de Responsabilidad Compartida.

performance indicators. It was divided in 6 areas: (i) Infrastructure and Logistics, (ii) Management Quality and Human Development, (iii) Legislation, Norms and Procedures Simplification, (iv) Foreign Trade, Exports Promotion and Incentives for local consumption, (v) Science, Technology and Innovation, and (vi) Financing and Access to Loans.

The program was ambitious and its deployment demanded not only a great quantity of resources, but also a substantial level of coordination between the Government, Prefectures and Municipalities. Their role was mainly the construction of physic infrastructures and the provision of basic services at the locations of quinoa production.

Although the quinoa productive chain identified the most important areas in need of action and planned concrete activities, something essential was missing: the definition of a clear and common objective. In our opinion, this resulted ultimately in the non-consolidation of the proposed plan and the disarticulated operation of the actors involved. It is also obvious that nothing was done to create an estimated investment budget according to the proposed activities. Hence, within the framework of this plan, only the funds donated by the Kingdom of the Netherlands were, in fact, invested.

Areas of intervention within the quinoa productive chain

In the area of ***Infrastructure and Logistics***, the plan was especially focused on road infrastructure in the producer zones, prioritizing the construction and/or improvement of roads and the construction of bridges. This was aimed at reducing quinoa transportation and commercialization costs. The authors estimate that the transportation costs from the gathering centers to the processing plants could be reduced from 20 to 30% with an improvement in the roads and the opening of new roads and highways. These estimates were based on comparisons of transportation costs in Bolivian routes with similar characteristics but in better conditions (i.e., instead of earth, asphalt or gravel). Even more, the construction of new roads in some production areas is a very important task, due to the fact that entire producer zones remain isolated from Bolivia six or seven months a year during the rainy season.

In relation to energy, the plan prioritized the improvement and extension of power lines, the construction of hydroelectric power plants, and a strategy to guarantee access to diesel fuel in the production zones. The objective was to reduce quinoa processing costs and mechanize the production activities of the southern part of the Altiplano. Finally, the Agenda included the

development of projects aimed at providing irrigation infrastructure to the production zones, with the objective of increasing crops yield. The institutions responsible of executing these activities were mainly the Prefectures of Oruro and Potosí as well as some small municipalities that had scarce resources but counted on the support of the Social and Productive Investment Fund (FPS, in Spanish²²). In seven years, the accomplishments achieved by the quinoa ABC in terms of infrastructure have been limited and disarticulated.

The area of *Management Quality and Human Development* was focused on strengthening the organizational and managerial capacity of the quinoa chain actors, by improving their internal control systems. In addition, efforts were made towards unifying these actors and augmenting their representation at a national level. These led to the implementation of workshops aimed at training leaders; the organization of multiple national meetings for producers, processors and sellers; and the execution of several training courses and workshops for producers. Even if the real impacts of those training and unification efforts are difficult to measure, there is no doubt that, at least, after so many years of workshops and meetings, the actors seriously focused on an internal dialogue process regarding their sector's development challenges. This process still remains and, in some ways, has paved the way for CPTS' intervention through the Quinoa Alliance.

The area of *Legislation, Norms and Procedures Simplification* focused on providing a legal framework for the producer organizations²³. In effect, these were facing several legal, commercial and tax issues, since they were not formally recognized as economic agents. The concept was to deploy a legal framework which would allow the quinoa producer organizations to have the same rights as the recognized economic agents. Four years had to pass from the time the idea was first proposed to be able to present the Law of Communitarian Companies²⁴ project to the National Congress, which has not yet been approved. The Law project is aimed at recognizing the producer organizations as formal economic agents so that they can: (a) have the right to sign contracts, (b) have a bank account, (c) access loans, (d) export, (e) be part of the national tax regime, and (f) invoice their sales.

²² FPS: Fondo de Inversión Pública y Social.

²³ These organizations are called "Organizaciones Económicas Campesinas" (OECAS).

²⁴ This Law project was presented to the Bolivian Congress on the 10th of January 2008 by the Superintendence of Companies (Superintendencia de Empresas, in Spanish), an actor that did not exist in 2002, when the subject was proposed.

This last point is of great importance for the clients of the producer organizations (the processing companies). In effect, the processing companies would be able to generate fiscal credit. Presently, the Bolivian tax system allows the accumulation of fiscal credit with the presentation of invoices for materials purchases. This fiscal credit can then be used to reduce the amount paid in Value Added Tax. Since the quinoa processing companies purchase raw quinoa without invoice, they cannot reduce the amount they pay in Value Added Tax so, in relation to other companies of other sectors, they are at a disadvantage. One of the most important production costs of quinoa processing companies is related to the purchase of raw grain (approximately 70% of total production costs)²⁵.

Before presenting the aforementioned Law Project, there was an attempt to implement an auto-invoicing mechanism for the processing companies. This way, these companies could compensate their disadvantage by receiving fiscal credit for their purchases of raw grain. This initiative never materialized. Nevertheless, in Article 19 of the Law of Communitarian Companies proposal, it establishes that the tax system applies to all producer organizations or Communitarian Companies. However, some problems exist in the definition of tax aliquots, namely, a progressive reduction of all different taxes aliquots, as follows:

- a) During the first three years, the taxes aliquots will be reduced by a factor of 10% to 30%
- b) Between the 4th and 6th year, by a factor of 30% to 50%.
- c) From the 7th year, by a factor of 50% to 100%.

Evidently, from the 7th year on, tax payment reductions would be a full 100%, which would be equivalent to the current situation. Thus the Law proposal encourages the establishment of Communitarian Companies but will not achieve the integration of these companies into the national tax regime. If the Law is approved, the Communitarian Companies will have a clear advantage over those companies which carry out the same activity but are not communitarian.

On the other hand, according to the Law proposal, the Communitarian Companies will be able to use and circulate Taxes Devolution Certificates (CEDEIM²⁶, in Spanish) which are currently applied to Bolivian exporting companies. With these Certificates, the exporters can

²⁵ Calculated from the cost structure of the companies ANAPQUI and JATARY in 2002.

²⁶ CEDEIM: Certificados de Devolución Impositiva

receive a refund of the money paid for Value Added Tax. It does not seem fair that other companies which do not have the same obligations can enjoy the same privileges.

The area of *Foreign Trade, Exports Promotion and Incentives for the local consumption* was oriented to accomplishing three objectives: (a) reduce the illegal quinoa sales to Peru by encouraging legal exports to that country, (b) promote quinoa grain and its value added products in international markets, and (c) promote internal consumption of quinoa.

In relation to the first objective, one of the problems that the Bolivian quinoa processing companies face is the disloyal competition of the quinoa “rescuers” (national and international) that sell the grain illegally, mainly to Peru. The competition is disloyal because the Bolivian processing companies support the producers in their supply programs in order to guarantee raw grain provisions. This implies covering the costs of the lands’ organic certification, providing the producers with work equipment, and training them. In several cases, however, those efforts have failed to maintain solid commercial relationships. Some producers prefer to sell the grain to those buyers that offer a higher price, refusing to supply those companies that have, in fact, worked for their own progress. This, indeed, weakens the commercial relationship and confidence between processing companies and producers.

Private companies have used different actions to stop these practices, for example, the signing of contracts, agreements and commitment letters with the producers. However, these legal mechanisms are simply an attempt to deter these practices, since private companies have, so far, not determined to take legal action against those producers who violate their contracts. First, because taking legal actions would be very expensive and it is very possible that in the current situation of Bolivia companies do not, in the end, win. And, second, because any legal action carried out against a producer who breaks a contract would result not only in losing that supplier, but the entire community of suppliers to which he belongs. Something curious is that even the producers who are partners in social companies fall into this type of unfair practice, but to a less significant level due to the minor incentives for doing so and the greater social control.

Peru is certainly an attractive market because internal quinoa consumption is greater than that of Bolivia²⁷, prices are higher and transportation costs from the Peruvian frontier to the Bolivian quinoa production zones are lower due to their proximity. Actually, there are some

²⁷ Only in Lima, around 7,000 tons of quinoa per year is in demand.

production zones that, during the rainy season, are impossible to reach by road; it is easier to access them from the Peruvian frontier. Moreover, as there are no proper controls at the frontiers, to bring quinoa to Peru without paying taxes is, indeed, very attractive. For this reason, the Shared Responsibility Agenda of 2004 defined specific actions aimed at establishing greater controls at Custom Offices and border crossings, and keeping records of the quinoa quantities leaving the country.

Although there are no exact figures of quinoa quantities being sold illegally, the sector's companies consider that before these technological advances, and the subsequent increase in processing capacity, the amount of quinoa sent illegally to Peru was greater. In effect, even if agricultural production of quinoa was not enormous, there existed an excess of quinoa that could not be processed due to the reduced capacity of local processing companies. Today, these companies, with their increased processing capacity, compete for buying this excess quinoa, to the extent that they have promoted smuggling control measures at the borders with good results. Thus, the reduction of quinoa smuggling has been fundamentally reduced by the augmentation of local processing capacity. Before the technological change, only 35% of quinoa agricultural production was processed, whereas at the present time, in contrast, companies, as stated previously, can process around 85% of that production.

As far as the promotion of exports is concerned, actions were aimed at financing the participation of the Bolivian companies in different international fairs, organizing training courses in exports management and carrying out export market studies. Finally, in order to promote the internal consumption of quinoa, efforts were focused on including quinoa in the diets of specific and concrete social groups, such as school breakfast programs, maternity subsidies, and the army and police food program. There has not been an extensive, open-ended campaign aimed at the entire population. Currently, quinoa consumption is still considerably reduced and limited to the western part of the country.

The area of *Science, Technology and Innovation* was oriented to promoting the coordinated work of various public and private institutions with expertise in the sector and linked to innovative areas within it. The defined agenda included a regional program for soil and irrigation management, a production system with certified seeds, the recovery of traditional technologies, the development of new sowing technology, fertilization and plagues control, and the development of new harvest and post-harvest technology with an organic focus. It is

necessary to mention that no public institution committed resources for research and development, and for the entire set of R&D activities described above, resources were limited to less than US\$50,000, derived from the US\$4 million fund donated by the Kingdom of the Netherlands. It is clear that with such limited resources it is simply not possible to address an ambitious research process.

At that time, CPTS had a different source of financial support for R&D activities. During the time in which the Shared Responsibility Agenda was established, CPTS had made some progress in the development of processing technology and its commitment was to promote such technology once it was fully realized. For the development of the first prototype of processing technology, CPTS invested approximately US\$200,000²⁸, which allowed this goal to be accomplished. Up to the present, the members of the Quinoa Alliance have achieved the most important results. They transformed the quinoa processing technological matrix, increasing significantly processing capacity and improving their productivity indicators, as has been previously stated.

The new challenge now is focused on the augmentation of quinoa agricultural production with the implementation of appropriate technology. For this purpose, CPTS will invest nearly US\$1 million up to September 2009, the date on which the first agricultural productive unit (prototype) will be up and running.

The area of *Financing and Loans Access* pursued the creation of financing mechanisms which offer better capital access conditions to producers and processing companies. For this, different micro-financing institutions were allocated with resources to execute the corresponding loans. However, these financing mechanisms are not yet adequate to the capital needs of larger projects for processing companies and agricultural producers. Besides, during the past few years, some public institutions and non-governmental organizations have intervened, in a disjointed manner, in making donations and granting subsidized credits that have sadly discouraged a more active participation on the part of financing institutions.

On the other hand, the most important processing companies of the sector had, as their key financiers, their international buyers and not the national financing system. The international

²⁸ From the technology manufacturer perspective (CPTS and IMA), the simple rate of return on investment reached 150%, and the payback period was 8 months. This calculation considered the investment in the first prototype (US\$ 200,000) and the cash flows generated by the sale of the 5 technological units.

buyers allocated financial resources at reduced interest rates and without the necessity of following any specific or complex procedures for obtaining loans. Indeed, national financing institutions must readjust their credit lines as well as other financial products to the necessities of the growing, and more demanding, quinoa sector that will not simply need micro-credit financing.

From productive chains to productive complex

In 2006, under the new Government, the concept of productive chain was changed to “productive complex.” This term adds a territorial dimension to the productive chain. Within this new conceptual framework, the productive chain must be referred to as a defined territorial space which presents comparative advantages with respect to other regions. The objective is to define the productive potential of each region and plan its development.

Even if that policy is not yet well established, it is important to take into account that, currently, many quinoa processing and value-added quinoa products companies are not located in producer zones, but in cities like La Paz, El Alto, Oruro and Potosí. Thus, the economic dynamic of the sector is not referred to through a defined territorial space. In order to integrate the entire value chain into a determined territorial whole, it is necessary to provide them with infrastructure – physical (roads, power lines, gas pipelines, and teledensity), social (health and education) and institutional (access to credit and risk management tools). These tasks require confronting a great challenge, and insist upon a coordinated effort between the Government, Prefectures and Municipalities.

The lack of capability on the part of the Government to consolidate a national development plan for the quinoa sector has resulted, in many cases, in disjointed and reductionist actions. Similar to this, most efforts to support the quinoa sector have been similarly disjointed and focused only on a small portion of the productive chain. Logically, the impact anticipated was in no way accomplished.

In many cases, poorly integrated actions, donations and subsidies aimed at a reduced number of beneficiaries had little or almost no contributory effect in solving the fundamental problems. On the contrary, these actions diverted the attention of decision makers to less important objectives. The donations led to other short-term perverse effects. From the financing services market point of view, the donations did not stimulate incentives for financing

institutions to take on a more active role. From a productive point of view, these paralyzed various producer projects, who suffered under the false expectations created by an anticipated “gift” that never came.

Evidently, it is easier to invest in specific or isolated projects, than in comprehensive development projects that encompass a long-term aim which incorporates larger and more ambitious objectives. In the end, however, there is a risk of losing one’s direction and to a great extent; this has been what has happened in terms of public policies for the sector.

The Quinoa Alliance project is holistic in nature and includes various elements from the intervention plan for the quinoa productive chain. However, two elements differentiate the proposal of the Quinoa Alliance from the proposal of the quinoa productive chain. The first concerns the definition of a quantifiable productive goal for the sector; the fact of establishing a concrete productive objective has allowed the public and private institutions to realize the magnitude of the challenge and reengage actions that had been abandoned.

The second element is related to scientific knowledge. Before, what had to be done was known; now, how to do it was known. The proposal of the quinoa productive chain recognized that the development of the sector needed technological advances, but did not give due importance to it. Four years after signing the quinoa ABC, and given the achievements accomplished at the quinoa-processing link, the decision makers now realize the great importance of the technological development that has occurred. Now there is the scientific knowledge that allows the discerning of a different future for the Bolivian Altiplano; a future not based on subsistence agriculture but on sustainable and profitable agro-industry.

7 THE NEXT STEP: AGRICULTURE

The great challenge that the sector is facing now is to achieve a sustainable increase in the agricultural production of quinoa, given that this link constitutes the new bottleneck of the productive chain. The new quinoa-processing technology presently allows, as mentioned earlier, the processing of almost all agricultural production. In order to achieve greater development, the agricultural frontier needs to be expanded in a sustainable manner.

Today, agricultural production is characterized by an intensive use of labor force with little commensurate use of technology. Even if a great extension of communitarian lands for quinoa cultivation were to exist, the areas to be exploited are limited to small parcels of land.

This is due, fundamentally, to the lack of soil management systems and the absence of proper sowing, harvesting and post-harvesting technology, which hinders the increase of those cultivation areas under sustainable conditions. At present, a quinoa producer can only sow the quantity that the labor force available in the family can harvest. In the vicinity around the production zone, there is no labor force market, the population is scarce and scattered as migration has left an extended territory with a population density of only 0.5 inhabitants per km².

Recent research and trials carried out by CPTS have shown that the region is agriculturally viable; in fact, it can be converted into a development magnet for the country. Trials made in the field indicate that, with the introduction of proper technology, it will be possible not only to increase crops yield significantly, but also to substantially enlarge the Altiplano's agricultural boundary in a sustainable manner, using lands that, for decades, have been considered not at all suitable for agriculture. In fact, these lands have resulted in being of the best quality for quinoa cultivation.

The involuntary contribution of NASA

For decades, some research was carried out regarding quinoa cultivation in the Altiplano. However, only since 2007 has fundamental scientific knowledge on quinoa cultivation requirements been acquired. NASA actually made an important contribution through its web page, in its 1996 publication entitled *Quinoa: Candidate Crop for NASA's Controlled Ecological Life Support Systems*. This publication guided CPTS's research and showed significant contradictions with what was known about quinoa until then. The study has three main fundamental conclusions:

- a. Potassium is one of the most important macronutrients for quinoa. Apparently, it is fundamental for quinoa growth, since it is needed for protein and enzyme synthesis and activation, and also for photosynthesis and associated metabolisms; furthermore, it appears to be vital for retaining and maintaining proper water balance for quinoa growth under the arid conditions on Bolivia's Altiplano.
- b. Calcium and magnesium, which are found in high percentages in both leaves and seeds, must also be considered as vital macronutrients (just like potassium), due to their function in plant growth (for instance, magnesium activates several enzymes). However, magnesium, calcium and potassium are found with much higher percentages in leaves

and seeds in plants grown under hydroponic conditions than under field conditions. This means that the inherent lack of availability of these macronutrients in soils is one of the fundamental factors that diminishes the quality and yields of quinoa production. Therefore, this is an issue that must be addressed using appropriated fertilizers, together with the right amounts of water during the critical stages of plant growth.

- c. The photoperiod in Bolivia's Altiplano, with relatively high instantaneous photon flux levels, is about 8 hours during summer (i.e. during December through March), when most of the plant growth takes place. The high instantaneous flux in traditional quinoa cultivars is due to the Altiplano's altitude (i.e. over 3,600 meters above sea level) and also to the diffused irradiance created by sunlight reflection off of the salt flats (the total area of Uyuni's salt flats is about 10,000 squared kilometers), which significantly increases the irradiance over quinoa cultivars located at distances beyond 120 kilometers from the salt flat's borders. (Note that diffused irradiance does not significantly diminish because of hills interposed between the salt flats and the quinoa cultivars).

The first two conclusions, which are based on the studies for NASA's CELSS Program, sharply contradict what is currently accepted for quinoa cultivars regarding soil requirements. The following paragraph, translated from a well known FAO technical publication in Spanish²⁹, is simply an example of such a contradiction: "*With regard to soil, quinoa prefers ... a moderate content of nutrients, since the plant has a high demand for nitrogen and calcium, a moderated demand for phosphorous, and a small demand for potassium.*" This publication contains the results of hundreds of studies on soil (nutrients and pH), water, radiation intensity, climate and temperature carried out in Denmark, England, USA, Chile, Colombia, Bolivia, Peru and Ecuador. As incredible that it may appear, scientists have overlooked not only the importance of potassium but also that of magnesium, as well as the nutrient synergies which apparently take place among several of the macronutrients³⁰. Those effects could only be seen under hydroponic conditions, which allow for unlimited and constant supply of nutrients. (This is the best way to establish the content equilibrium of such nutrients within the quinoa tissues and seeds.)

²⁹ See Mujica S., Sven-Erik Jacobsen, Juan Izquierdo, and Jean Pierre Marathee (2001).

³⁰ Aside from the normal requirement of magnesium to produce chlorophyll, no study for quinoa growth conditions that CPTS is aware of, except that of the NASA study, takes magnesium into account as a vital macronutrient for quinoa.

The ignorance underlying those technical characteristics resulted, for many years, in not applying correct measures to avoid the soil's degradation, in not extending agricultural expansion under adequate conditions, and in not increasing the crop's productivity. The sandy and salty latent lands around the salt flats contain large quantities of the quinoa macronutrients mentioned above (soils are particularly rich in potassium, magnesium and calcium), which are being exhausted over the years since no rapid natural replacement has been taking place. Furthermore, the use of deep plowing techniques contributes to further loss of macronutrients due to erosion caused by high velocity winds'. These two factors, combined with the use of harmful pesticides, which eliminates useful soil microorganisms, are significantly degrading the productivity of soil currently used for quinoa cultivars.

On the basis of the new knowledge acquired, CPTS developed approximately 16 scientific investigations that have not only confirmed NASA's results, but also has allowed one to look beyond them. In this way, CPTS has designed a methodology for the recovery of degraded and eroded soils, a methodology to rehabilitate virgin soils, and a methodology for soils' comprehensive management (either recovered or rehabilitated). As part of these methodologies, CPTS also has developed a minimal farming system, an organic fertilizer that makes all quinoa requirements bio-available, an organic and innocuous pesticide for human beings based on saponin and suitable for plague control, a conic sowing system for controlling the parameters which influence the physiological maturity of the grain, among others. The application of these methodologies in experimental hectares resulted in the increase of the crop's yield, the improvement of the grain's nutrient content and the optimization of the biomass-grain rate. In addition, the methodologies allow for a homogeneous physiological maturity of the grain, making possible a mechanized harvest, something that was unthinkable years ago.

Furthermore, the research has led to one of the most important of its discoveries: that the sandy and salty soils ("poroma"), abundant in the production zones but, for years, it was thought that this type of soil was unsuitable for any food cultivation. In fact, it is the best type of soil for quinoa crops, though no other food can grow in it. At the production zones, there are approximately 4 million hectares of this soil type. The project proposed by the Quinoa Alliance is aimed at rehabilitating one million hectares of poroma soils for quinoa cultivation.

The development of agricultural technology and the model proposed by the Quinoa Alliance

Thanks to the knowledge acquired during the last few years of research, CPTS has designed and, in cooperation with IMA, has built farming machinery set prototypes, which consist of the following cleaner production farming equipment:

- a. Planter. Developed for in situ fertilization and seeding using minimal farming techniques. This equipment will allow savings because of the significantly decreased quantities of fertilizers that will need to be applied in situ, and will significantly reduce soil erosion, since no sandy soil plowing will take place.
- b. Harvester. Will cut and collect the quinoa shoot ends (*panojas*) with minimal seed losses; and will cut, mill and collect the stems with their leaves to be mixed later with manure to produce compost, in order to return significant amounts of nitrogen, phosphorous, magnesium, calcium and potassium to the soil. Furthermore, the harvester will not pull the roots out of the ground, which will stabilize and add structure to the sandy soils.
- c. Dryer. Will dry the seeds using heat produced from sunlight, and an airflow created by an ingenious chimney design. This innovation will allow drying physiologically matured seeds in less than 3 days, to prepare them to be threshed, without having the current losses and contamination of seeds by rodent and bird scum, and with stones and rodent and insect fluids, which occurs during the standard accommodation (*empavillado*) and sun-drying of quinoa plants.
- d. Thresher and sorter/cleaner. Will innovate the way threshing should take place without damaging the seeds, and without generating unwanted straw, which forms in large quantities due to current threshing practices (i.e. the entire plants are stepped on and pounded with heavy sticks or passed over with trucks. Also, some producers have threshers adapted from machinery designed for other crops, which are not satisfactory due to economic and efficiency reasons).

On the basis of the newly developed technology, the Quinoa Alliance proposes a development model aimed at implementing agricultural productive units equipped with this new technology. These agricultural units can be operated by one or more families, depending on the forms of social production organization which the communities decide to adopt. The first agricultural productive unit will be put into operation in September 2009. Its success will depend

on how quickly the technology adoption process will take place, as well as the achieving of the goals set by the Quinoa Alliance.

With the designed technology, each productive unit has the capacity for exploiting 250 hectares per year. Therefore, in order to reach the goal proposed by the Quinoa Alliance (1 million hectares of production per year), ultimately 4,000 productive units will be required³¹. In addition, each 10 productive units will count as one quinoa processing plant with the same characteristics of those which are already installed. The introduction of the new agricultural technology can represent a huge leap in the productivity scale of quinoa producers since currently they cultivate from 1 to 3 hectares of quinoa per year.

The achievement of the objective of one million tons per year would result in an outcome, in sales, of US\$3,000 million at current quinoa prices, or US\$1,500 million, assuming that quinoa prices could decrease by half. In either case, the quinoa would become the most important agricultural product in Bolivia, contributing approximately US\$450 million to the national GDP³².

The Quinoa Alliance believes that this objective can be accomplished. However, more than simply technology and investment capacity for both social and private companies will be needed.

The Government must invest in infrastructure – physical (roads, power lines, gas pipelines, and teledensity), social (health and education) and institutional (access to credit and risk management tools). Furthermore, it will be needed to support and strengthen the productive chain of other sectors that have synergistic relationships with the quinoa sector (for instance, the camelids productive chain). Finally, the mechanization of quinoa agricultural activities will require numerous machinery manufacturers, which must be capable of constructing equipment and parts with the necessary quality and production speed. The challenge is indeed ambitious, but it is necessary to consider the entire magnitude of this challenge in order to avoid dissipating the efforts required and provoking the failure to accomplish its expected impact.

³¹ Considering that community lands will be used, and their use is restricted to members of the same community, it is expected that the productive units would be managed by peasant families belonging to the same community.

³² On 2007, the total Bolivian GDP was US\$4,035 million.

8 CONCLUSIONS

Our analysis reveals that the technological innovation in quinoa grain processing have had a significant impact on the productivity of the Bolivian companies dedicated to this activity, which has resulted in a considerable augmentation of its exports and the sector's growth. This has come concurrently with a convergence process in productivity, the consequence of the process mode modification (of replacing batch operations with a continuous process) and the introduction of homogeneous production protocols inherent to the new technology.

The excellent results obtained have led to the natural creation of an alliance among the most important companies of the sector: producer associations and technology manufacturers. Perhaps this success would not have been possible without the prior intervention of the productive quinoa chain, which was initially kick-started by the Unit of Productivity and Competitiveness. Even when this intervention did not obtain the expected result in terms of consolidating the efforts of multiple institutions, it was important in terms of establishing a collective awareness on the importance of addressing the development problem in a holistic manner. Without doubt, this has paved the way for CPTS' intervention through the Quinoa Alliance.

To the extent that a small program such as the Quinoa Alliance has gotten tangible results, other institutions, public and private, have shown more interest in actively participating of the process. Hence, it is possible to think that in some cases where government capacity is limited in terms of generating and coordinating larger development programs, it is useful in order to concentrate intervention efforts into more limited and well-focused areas. This will trigger positive effects and lead to actions by the rest of the actors and sectors.

The fundamental objective of the Quinoa Alliance is to achieve the quinoa sector's sustainable development through the modification of its technological matrix in all links of the productive chain. The great current challenge is to increase quinoa agricultural production in a sustainable manner, which is why the research carried out during the last several years has focused on this objective. Recent research has shown that it is possible not only to increase crops yield significantly, but also to enlarge the agricultural boundaries of the Altiplano in a fully sustainable manner, using lands that, for decades, have been considered to be unsuitable for agricultural use yet, paradoxically, have been proven to be ideal for the production of quinoa. The research results have been the basis for the design of new agricultural technology specific to

the types of soils and ecosystems of these quinoa production regions. It is expected that the producers, equipped with this technology, will create efficient productive units which will allow them to manage a process of sustainable growth and long-term development.

Other agricultural-productive chains in Bolivia have enormous development potential. Nevertheless, it is necessary to resolve certain critical problems in the production process. This requires, in part, making well-focused investments on research and development to achieve a technological leap. Despite the fact that some people believe that such problems can be solved merely by importing technology from developed countries, it is essential to take into account that the major machinery and equipment manufacturers in the world do not produce customized technology for every agricultural activity, particularly those native to Bolivia and other Latin American countries, and therefore certain unique segments of agriculture production have remained unattended.

In order to reach the expected objectives, the technological innovation must come with parallel innovations in the institutions that promote development. The public sector has an important role to play in boosting coordinated policies aimed at promoting the adoption of these innovations. The generation of technology as well as its adoption is affected by deliberated public policies (e.g. infrastructure development, research funding and activities of agricultural extension), not deliberated policies (e.g. changes of commodity prices), and activities of the private sector. One of the challenges related to the design of development policies based on technological change is an optimal integration of public and private efforts.

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