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WHEY: A THEORETICAL ESSAY ON THE EVOLUTION AND DYNAMICS OF ITS PRODUCTIVE CHAIN

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Introdução
Whey is a by-product from the dairy industry, that until 20 years ago did not have any significant application nationally. However, a number of factors such as changes in legislation prohibiting its improper disposal, linked to advances in research on its nutritional properties and technological potential, has changed its image “from gutter to gold”. It was observed, that during this period it was observed the birth and development of a production chain for this, so far called by-product.

Problema de Pesquisa e Objetivo
Starting from the following research problem: what are the main aspects of evolution, structure and dynamics of the whey production chain? The aim of this theoretical essay is to discuss the evolution and dynamics of the whey production chain focusing downstream of the industry.

Fundamentação Teórica
It is discussed the structure and dynamics of production chains highlighting its connecting links and its surrounding environments (institutional, organizational and consumer). It is also discussed the concept, characterization, applications and environmental issues regarding whey, and the Brazilian reality of its market.

Metodologia
This article is characterized as a theoretical essay written from searches on major international scientific databases and from research in relevant literature in the field.

Análise dos Resultados
Whey production chain starts within the dairy production chain given that whey is a waste from cheese-making. Whey is an abundant and cheap input which is underused nationally. As for the industry, it has a coordinating role in the chain since it owns the whey processing technology. Regarding the dynamics, the institutional and organizational environment are responsible for important movements within the chain, by means of laws, resolutions and application of technologies and processes.

Conclusão
It can be concluded that the whey production chain is still incipient in Brazil but it has a promising future when taken into account its low cost of acquisition and its abundant and widespread availability. The chain is strongly coordinated by the industry (technology-push), and as for the dynamics, the main factors affecting the chain are changes in the institutional environment; and changes in the organizational environment.

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WHEY: A THEORETICAL ESSAY ON THE EVOLUTION AND DYNAMICS OF ITS PRODUCTIVE CHAIN

1. INTRODUCTION

Whey also known cheese whey or milk whey is a by-product of the dairy industry. It represents the milk aqueous portion that separates from the curds during conventional cheese manufacturing (Baldasso, 2008). In cheese making, there isn´t 100% conversion of milk into cheese, its yield may vary from 8.5% to 20% depending on the consistency of the cheese, thereby producing, in addition to cheese, the whey (Giroto & Pawlosky, 2001).

Until about twenty years ago, the whey did not have significant application in the national scenario, being used primarily for animal feed or being disposed in water streams (Santiago, 2013), thus, this by-product did not have a developed productive chain, given that when it was discarded, its use was done basically within for animal feed.

However, a number of factors such as changes in legislation (prohibiting the improper disposal of waste), linked to advances in research on the nutritional properties and technological potential of the whey began to modify this setting. As Smithers (2008) and Santiago (2013) stress in the last two decades the whey has been having its image modified, from "gutter to gold" given its nutritional properties and its technological appeal to the food industry. For instance, fresh whey began to be used on a large scale for manufacturing of dairy beverage and ricotta, and when processed, it has been considered as raw material for various products such as food supplements for athletes and children (whey protein concentrate, whey protein isolate, etc.), powdered lactose, lactic acid and even ethanol.

It is observed then, that during this period there was the birth and development of a productive chain for this by-product. Thus, the aim of this theoretical essay is to discuss the evolution and dynamics of the whey production chain focused downstream of the industry.

In addition to this introductory session this paper is divided into five parts. In the second session it is discussed the main aspects of productive chains and their dynamics. Following, the key aspects of whey showing its nutritional characteristics as well as environmental problems generated by it are addressed. The fourth session seeks to make a sketch of the whey production chain showing its evolution and dynamics, and finally, the fifth section deals with the final considerations of the study. It is worth noting that is not the purpose of this theoretical essay to cover exhaustively all the theoretical scenario that makes up this field of study. The idea is to introduce the reader to the subject and give subsidies for future immersion in the field.

2. PRODUCTIVE CHAINS: STRUCTURE AND DYNAMICS

The understanding of the economic reality now requires interpretations guided by a systemic environment, which involves not only the parts, but the whole and their interrelations (Pereira; Cario & Souza, 2005). In this sense its noteworthy highlighting the importance of studies on production chains, which requires evaluations of technical and economic operations of the various steps taken in the process of production and consumption of goods (from the provision of inputs, production and processing of materials up to marketing) and the environments (organizational, institutional, consumer) existing around the productive chain which are fundamental in building the chain competitive advantage.

According to Davis and Goldberg (1957) cited by Andrade (2015) agribusiness was a concept coined from the understanding that issues related to the activities of rural enterprises and

their organizational environment were much more complex than the simple agricultural activity within the properties. In this sense, Araújo (2007) defined agribusiness as the set of all operations and transactions involved since the production of agricultural inputs, the operations production in agricultural units, to processing, distribution and consumption of fresh or processed agricultural products. Similarly, Batalha (1993) states that the agribusiness production chain, refers to a set of techniques responsible for transforming raw materials into finished products, followed by the distribution and marketing in a linear sequence of operations. Thus, the chain expresses a set of economic actions that seeks to add value at every step by articulating specialized operations.

Hereinafter, as pointed out by Andrade (2015), Pereira, Cario and Souza (2005) and Zylbersztajn (2000) agro-industrial system or agro-industrial complex are consolidated terms in the literature, they are also called Commodity System Approach (CSA), which theoretical base is derived from the neoclassical theory of production, in particular the concept of input-output matrix; also worth noting is the concept of agri-food chain (*filière chain*), which is the product of the French industrial business school that applies the sequence of activities that transform a commodity into a product ready for the final consumer.

The use of the concepts of chains, production systems and coordinated subsystems generated large volumes of empirical research both in Brazil and abroad from the 1980s to the present (Zylbersztajn, 2005). The supply chain analysis is an example of a common approach for studying agribusiness, which focuses on successive stages of value creation in an organized sequence of enterprises (Lazzarini; Chadad & Cook, 2001).

Both the agro-industrial systems and the *filières* use the concept of successive production stages, from raw materials to finished product, in order to guide their analysis (Andrade, 2015). In this regard, typical transactions and the influence of institutional and organizational environments (which are configured as competitiveness determinants), are common to all chains regardless of the theoretical conceptualization (Zylbersztajn; 2000; Pereira; Cario; Souza, 2005). Figure 1 illustrates the generic model of the agro-industrial sector production chain as well as its typical sequence of transactions.

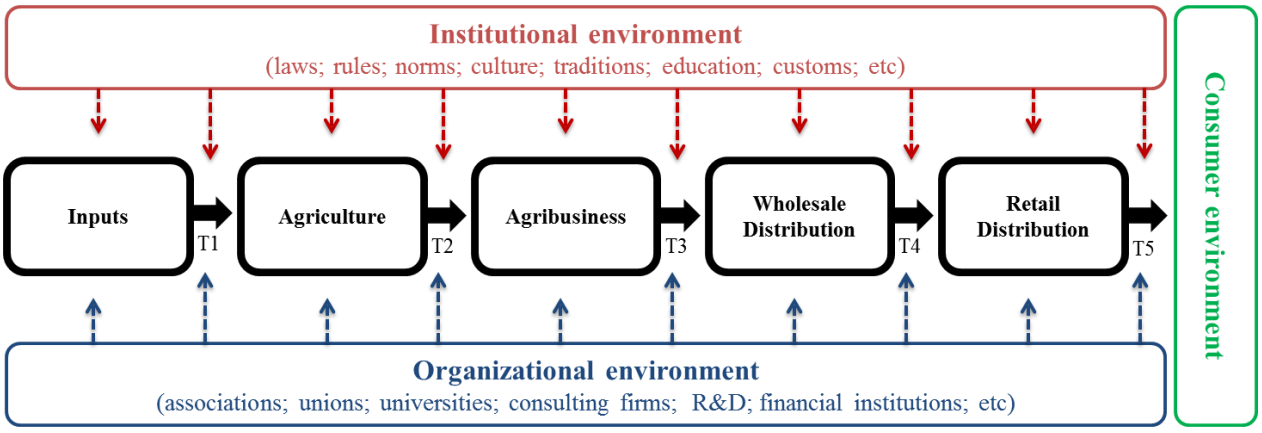

Figure 1. Agro-industrial system and its typical transactions
Source: prepared by the authors based on Zylbersztajn (2000) and Pereira; Cario and Souza (2005).

2.1 The links in the production chain

By analyzing Figure 1, it can be seen in the center (in black) the production chain, and surrounding it (in red, green and blue) the institutional, organizational and consumer environments.

As pointed out by Zylbersztajn (2000) when looking in detail at the links of the chain, on the left end there are the agents engaged in the generation of raw materials (inputs) and the farmers (agriculture) for the food industry. Such suppliers represent the most conflictive links in agribusiness, as they are far from the final market and therefore often fallen victim to asymmetric information, not to mention that these members' geographical dispersion and variety.

Agents working in the food processing are called agribusiness (Araújo, 2007; Zylbersztajn, 2000). For these authors, it is a set of activities performed by different sized companies that are responsible for transforming products of primary origin by adding attributes and therefore, adding value. On the one hand, agro-industry deals with its customer, the distributor agent (wholesale and retail), which needs to place the products on markets shelves and, on the other hand, deals with its supplier, the primary sector, whose them should divide the margins from the product´s sales.

The following link, the wholesalers, have the function of distributing products derived from agricultural industries to large urban centers through central platforms, whose main role has been to physically concentrate the products and allow retailers to fill their stocks (Zylbersztajn, 2005; 2000). The final link before products reach consumers is composed by the retailers, which have the function of making products available to consumers. As pointed out by the author, the retail distribution has become highly specialized and performed by agents with different characteristics. The sector is characterized by low margins and high rotation, which confers the companies with high profitability potential, but also intense competition among the various competing companies.

2.2 The surrounding environments of the production chain

In addition to the production chain links, Pereira, Cario and Souza (2005) point out that in order to study productive chains (and the firms within it) is important to consider the internal and external economic environments surrounding the chain and the significant impacts on the chain´s governance and coordination forms and thus, on its competitive performance.

The consumer environment is the focal point in which the flow of the chain converges (Zylbersztajn, 2000). The final consumers buy the product to satisfy their needs and desires, which vary according to household income, preferences, age, among other social and economic factors (Blackwell; Miniard; Engel, 2009).

In Poulain's (2006) view, food does not move or is transformed by itself; transformation processes, preparation and consumption involve, above all, human subjects. That is, from the fields to the consumer's table, food not only undergoes several transformations on its physical form, but also in this process it takes on different meanings in a systemic model that comprises perspectives that involve the food and their different local and global contexts inter-related.

Bongoni *et al.* (2013) stresses that in recent decades the opinions, needs and expectations of consumers about food have changed dramatically. For these authors, in addition to the sensory preferences, the health benefits generated by food are increasingly important factors for the choice of products. Bragante (2012) complements by saying that due to globalization and the technological advances, consumers in general have gained awareness of global trends as well as the recognition of their rights, factors that are influencing the time of purchase. Thus, consumers are more demanding and less loyal to product brands forcing companies to continuously differentiate themselves. In this way, the marketplace should move towards a consumer-oriented market, since the behavior of the modern consumer society inhabitants challenges the traditional segmentation (Dagevos, 2005).

Thus, it is important to highlight the reservation made by Zylberstajn (2000) that consumers may be far from the production stage, since much of the large supermarket chains are globally supplied. For the author, this implies that the information must be fully coordinated, especially when demanded by the final consumer; this fact, may require very complex relationships among the productive agents, going beyond typical market transactions.

The organizational environment includes those agents responsible for the provision of a set of public and private goods, upon which the company has no individual control, and that influence and affect its individual strategies, such as: logistics infrastructure dependence; the need for joint cooperative action among rivals, suppliers, distributors, public and private research centers; financial institutions, consulting firms, etc. (Pereira; Cario & Souza, 2005; Farina, 1999). Generally speaking, this environment includes those structures (companies and organizations) created to support and sustain the operations of the production chain (Zylberstajn, 2000).

The institutional environment aggregates the legal systems that are important in resolving disputes (laws, rules); traditions and customs; macroeconomic policy; trades and industry taxation) that act on the production chain (Pereira; Cario & Souza, 2005; Machado Filho *et al*., 1996). Still according to the authors, sectoral regulation and deregulation processes and commercial openness, represent institutional changes that increase the competitive pressure and alter strategies, impacting directly the organizations within the productive systems.

As Zylberstajn (2000) emphasizes, change in organizations can occur quickly; however, changes in the institutions are more difficult to occur. Therefore, companies' dynamics must adapt to the institutional environment, but also may sought to modify it, exerting pressure on the legislature in search of more appropriate rules that fulfills their interests. The author concluded that the understanding of organizations and especially the institutions, it is important both to define private strategies and public policies.

3. WHEY

3.1 Characteristics, applications and environmental issues

In cheese making, there isn´t 100% conversion of milk into cheese, thereby producing, in addition to the cheese, the whey (Giroto & Pawlosky, 2001). It is estimated that in order to produce one kilo of cheese 10 liters of milk are spent approximately, which then results in approximately nine liters of whey (Baldasso, 2008; Ribeiro, 2004). Thus, whey, also known as cheese whey, milk whey or even lactose whey is a by-product of the dairy industry, that is the milk aqueous portion that separates from curds during conventional cheese making. It is a yellowish-green liquid, with slightly acid or sweet flavor that varies depending on the type of coagulation which the milk was subjected (EMBRAPA, 2006).

As Baldasso (2008), Miller, Jarvis and McBean (2000) highlight the predominant type of whey produced in Brazil is the sweet whey, derived from the manufacture of ripened hard, semi-hard or soft cheeses (Prato, Swiss, Provolone, Mozzarella). It is the whey obtained from the enzymatic coagulation and its pH ranges from 6.3 to 6.6 (Giraldo-Zuñiga, 2004). On the other hand, the acid whey with pH ranging from 4.3 to 4.6 comes from the acid coagulation of milk for manufacturing of cottage cheese, cream cheese and commercial casein (Giraldo-Zuñiga, 2004; Miller & Jarvis, 2000; Mcbean, 2000). However, it is noteworthy that with the rapid growth of the Greek type yogurt market, acid whey production tends to rise in the Brazil (Antonialli, 2015).

Whey is basically composed of water (93%) and only 7% dry matter or solids (EMBRAPA, 2006). As highlighted by Abreu and Gajo (2012) and Baldasso (2008), the whey retains on average 55% of all milk nutrients.

Lagrange and Dallas (1997) further emphasize that whey contains most of the vitamins present in milk, such as vitamin C, B6 and B12, pantothenic acid, riboflavin and thiamine. And as Smithers (2008) highlights, the whey proteins have an exceptional biological value which exceeds that of egg proteins in 15%. Mcintosh *et al.* (1998) have found that whey proteins have anticarcinogenic and antiulcerogenic action. Macedo (2010) also notes that these proteins may be used for therapeutic purposes, such as antioxidants and as antihypertensives.

Thus, Prazeres *et al.* (2012) remark that whey contains a high added nutritional value; and because of that, is now seen by the industry as a rich and varied compound of proteins with chemical, physical, nutritional and functional functions (Bounous, 2000).

Nevertheless, even with the various possibilities of whey exploitation that have been discussed over the past years, about half of the world´s production is still not harnessed, then being discarded as effluent into water systems or directly into the soil, resulting in an alarming environmental pollution, as well as a significant loss of food energy and major economic losses (Baldasso, 2008; Sisso, 1996).

It is known that whey is the main source of environmental pollution generated by the dairy industry. As pointed Baldasso (2008), the pollutant load, represented by the Biochemical Oxygen Demand (BOD) can reach 60.000 mg $O^2.L^{-1}$. Which according to the author, in a plant with an average production of 10,000 liters of whey per day, pollutes the equivalent to a population of 5,000 inhabitants. In this way, a solution to this pollution problem has become urgent, prompting governments and other regulatory authorities to restrict and/or prohibit the disposal of untreated whey (Smithers, 2008).

The resolution nº. 430 from May 13th 2011, which establishes the parameters, conditions, standards and guidelines for effluent discharge management in receiving water bodies (BRASIL, 2011), added and partially amended the resolution nº. 357 from March 17th 2005 from the National Environment Council - CONAMA, which provides the classification and environmental guidelines for the framing of surface water bodies, as well as establishes the conditions and patterns for effluent discharges (BRASIL, 2005). Article 3rd is here highlighted:

> Art. 3rd: Effluents from any pollutant source can only be dumped directly into receiving water bodies after proper treatment that satisfy the conditions, standards and requirements set out in this resolution and other applicable rules.

However, Smithers (2008) stresses that even though the whey pollution power is somewhat well known, this by-product is also an excellent source of functional proteins, peptides, lipids, vitamins, minerals and lactose. In this manner, with the technology continuous development and an increasing environmental responsibility by the industries, the whey image is rapidly changing from effluent to a valuable source of nutrients (Baldasso, 2008).

3.2 The Brazilian reality of the whey market

According to Stiles (2012), the US is the global leader in production and export of whey powder and its derived products. According to the author, the country accounts for 20% of the world´s production and 36% of the global businesses. Brazil, on the other hand, is among the world's largest whey and whey-based products importers (Valduga *et al*., 2006).

However, as pointed Alves *et al.* (2014), there is a possibility of transforming this by-product into a national opportunity, because the food and pharmaceutical industries are widely

using whey and its derived products as raw materials and doing so, they have to rely on foreign purchases.

Brazilian data on whey availability is highly inaccurate, because a significant portion of cheese is produced by small businesses, that without structure to process whey end up using it to animal feed and discarding the surplus (Silva *et al*., 2013).

Complementarily, Pereira, Jardim and Santos (2009) pointed out that in 2009, there were in the country about five thousand dairy plants, and that approximately 50% of these were located in the state of Minas Gerais (MG), and according to Nadai *et al*. (2013) and IBGE (2006), MG is the state with the highest production of milk and dairy products, and most of these dairy plants did not perform wastewater treatment.

Based on the aforementioned, Alves *et al*. (2014) characterize Brazil as a whey importing country. According to the authors, although the country is ranked in sixth in milk production, it still imports a high amount of whey, given that its processing requires the application of technologies not yet adapted to the national reality. Silva *et al*. (2013) then conclude that even with an increase in domestic milk production, a significant portion of the whey used in Brazil continues to be imported because there is no processing in the country that meets the needs of the producing industries.

This processing inadequacy is caused by the fact that small dairy plants do not have the financial capacity to install the equipment required for whey processing, since they have to face large investments if they want to transform the whey into a value-add product (Alves *et al*., 2014; Valduga *et al*., 2006; Peters, 2005). However, a way out and possible trend is the installation of central processing units that receive whey produced by cheese makers in a given region.

According to Santiago (2013), in an article published on *Dinheiro Rural* magazine, the Union of Dairy Industries of São Paulo (Sindleite) estimates that Brazil already has the capacity to produce 115,000 tons of whey powder per year but produces only 40,000 tons and imports about 28,000 tons. According to the president of the entity, the greatest obstacle for this market to grow nationally is technology. “Whey is very perishable, it must be kept refrigerated, and transportation is expensive”, he states. “Even so, we believe the sector is growing above 10% per year and Brazil is heading towards self-sufficiency.” In this sense, it is necessary for the industry to invest in technology and innovation in order to better exploit and capitalize this raw material.

4. THE WHEY PRODUCTION CHAIN

Taking into account the widespread cheese production in the country (mostly carried out by small and medium dairy plants) and producers’ lack of interest concerning the use, application and disposal of whey (Serpa; Priamo & Reginatto, 2009), data on the availability of the whey as previously pointed out by Silva *et al.* (2013) is highly inaccurate.

Searches on databases and websites such as IBGE, ANVISA, MAPA, Milkpoint, among others corroborate the exposed by foregoing authors, given that the authors of this particular essay have not found consistent and relevant data on the domestic production of whey. This suggests a lack of studies and lack of interest in the area (Serpa; Priamo & Reginatto, 2009). In this regard the efforts of the authors of this particular theoretical essay is to trace a sketch of the whey production chain focusing on the downstream of industry, based on the literature and available data on whey.

Whey production chain begins in what can be considered the "central position" of the cheese and dairy productive chain, since whey, a by-product of cheese making is the input (raw

material) for a new production chain. Figure 2 illustrates the emergence of the whey production chain from the cheese and dairy production one.

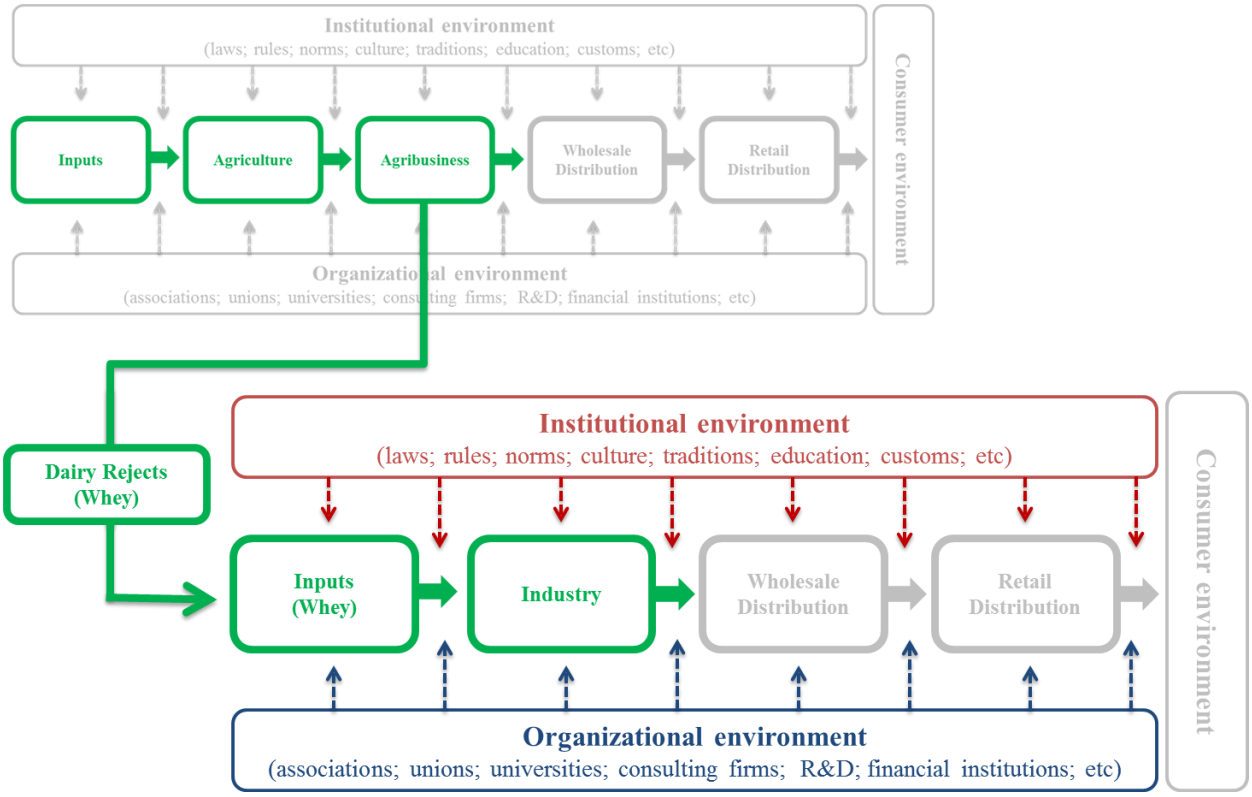

Figure 2. Origin of the whey production chain (focus on downstream of the industry).
Source: prepared by the authors based on Zylbersztajn (2000).

4.1 Inputs (raw materials)

According to the data portal Milkpoint (2015) Brazilian cheese market grew 9.4% in volume and 7.7% in revenue per year from 2006 to 2013, and should increase its growth rate until 2017, reaching revenues in the order of R$ 19.9 million and 1.659 million tons of cheese. Thus, taking into account the metric that to make one kilo of cheese an average of ten liters of milk are spent, is estimated for the year of 2017 the production of 14,931,000 tons of whey, thereby, analyzing the initial link in the chain it is noticed that the input – whey, is an extremely abundant and inexpensive raw material.

However, some points should be highlighted when considering the whey as an input: 1) fresh whey is extremely perishable – due to its high content of organic matter and water (Siqueira, Machado & Stamford, 2013) - which makes its logistics complex, fact that should be treated with caution by the agents involved in the chain;) whey quality – for further processing by the industry – is not standardized (Antonialli, 2015), there may be variation in acidity and pH, solids content, fat, and other physicochemical factors that might affect the quality of subsequent derived products and; 3) availability of whey collection – that despite abundant, is dispersed given that much of the national cheese production is carried out by small or micro enterprises (Silva *et al.*, 2013), which therefore makes it difficult to collect and transport to drying and concentration industrial plants for further processing.

4.2 Industry

Fresh whey has historically been used in the manufacturing of dairy beverages, modified milk, ricotta, as well as it has been used for animal feed and as an agricultural fertilizer (Alves *et al*., 2014; Sisso, 1996).

Over the past decades, especially over the past 30 years, the development of new technologies and research has allowed the creation of various products derived from whey. As pointed out by Antonialli (2015), Rocha (2013), Ramos (2010) and Smithers (2008) currently whey-based products compete with many other products for market shares, being present in a large number of items such as chocolates, fillings, toppings and ice creams.

Thus, nowadays, whey has been widely required by the industry (Gernigon *et al*., 2010), since when technologically processed it is likely to have many applications, due to its technical characteristics that ranges from its use as a food ingredient to the production medications (Alves *et al*., 2014; Smithers, 2008).

As pointed out by Alves *et al.* (2014), the government has been encouraging the development of technologies that allow the use of whey in a manner that is viable both from an economic and technological standpoint. Thus, the increase in demand for whey and the increasing development of processing techniques have transformed this by-product into something profitable (Balagtas *et al*., 2003).

Approximately 20 years ago, Sisso (1996) sketched out a model of the possible secondary products and technologies that can be generated from whey processing. Figure 3 shows an adapted scheme comprising such derived products and technologies based on the model proposed by the author.

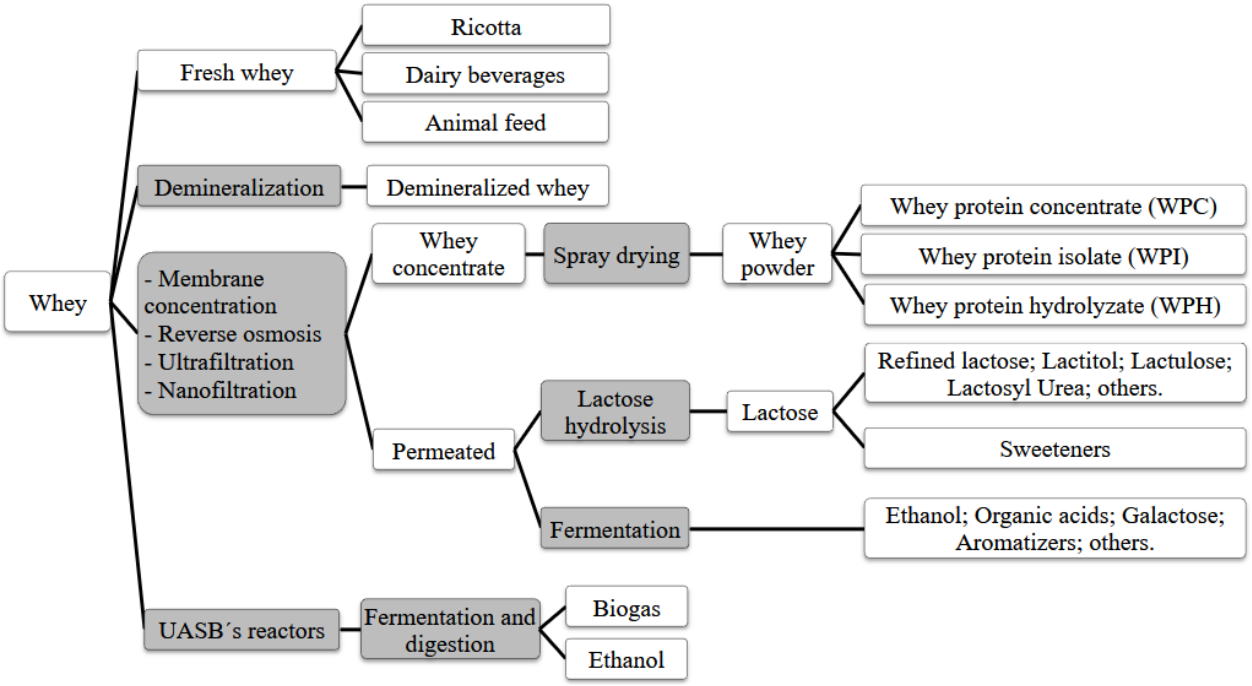

Figure 3. Scheme of derived products obtained from whey processing and used industrial technologies.
* White boxes represent derived products obtained from the application of technologies for the whey processing;
** Gray boxes represent some of the used technologies.
Source: prepared by the authors based on Sisso (1996).

According to Valduga *et al.* (2006) the most important whey-based products are: 1) demineralized whey (often used for infant formulations); 2) refined lactose; 3) whey protein concentrate (protein content ranging from 35 to 80%) and; 3) whey protein isolate (containing over 90% protein).

Whey powder production is the most elementary way of adding value to the product, and the production of whey protein concentrate powder (WPC) has lately been seen as very attractive and profitable alternative, due to the great consumers' demand (mostly gyms regulars and elite athletes) this product has been reaching high market values (Pisecký, 2005; Peters, 2005). The use of powdered whey and whey protein as food ingredients are increasing extensively within the food industry, as technological capacity of industries to produce such derived products has also been increasing (Alves *et al*., 2014; Philippopoulos; Papadakis, 2008).

4.2.1 Elementary forms of adding value

One of the first moves made by the farmers and the dairy plants in order to reuse whey, was to use it fresh for animal feed. However, it is clear that despite helping reducing the environmental problem (by not disposing whey) this activity, in general, does not add value to the product.

As stressed by Jank and Galan (1998), after the implementation of the Real Plan in the early 90s, there was a period of economic stability in the Brazilian economy, market deregulation, trade liberalization and purchasing power recovery by the poorest social classes, such facts according to the authors, led to a significant increase in milk and dairy products consumption. In this way, Carvalho and Oliveira (2010) reported that large investments were made in the country with new companies entering the dairy market.

In this regard, the most elementary way found by industries to add value to whey was by the production of the so called dairy beverages. According to Viera (2015) and based on national legislation (ANVISA, 2002), dairy beverages are dairy products resulted from the blend of milk and whey (fresh or powdered), which can be added of fruits, pulps, flavoring agents, among other ingredients, and it also may be or not fermented. According to the legislation, for fermented dairy beverages is permitted to add up to 50% of whey, as for unfermented is permitted to add up to 70% of whey in the blend.

A second alternative found by the industry for reusing whey which requires a low level of technological and financial investment is the manufacture of ricotta (Ramos, 2012; Pabouef *et al*., 2011).

4.2.2 Processes and technologies to value addition

With the development of technology and research, new ways to add value to whey have emerged. Started in Brazil in the 1970s one of the major technological advances that allowed great value addition and diversification of the portfolio of products generated from whey was the processes of concentration and separation of nutrients through membranes, such as nano and ultrafiltration and reverse osmosis (Carvalho & Maubois, 2010).

The whey concentration process (reduction of water content) increases its shelflife facilitating the logistics process, but its main function is to increase the productivity for the drying process, namely, manufacturing of powdered through spray drying (Perrone *et al*., 2011).

By itself, whey powder is an ingredient already in a great demand by industry, being incorporated in the manufacturing of breads, pastas, cakes, toppings, among others (Rocha, 2013; Dallas, 1999), however, one of the best ways to add value to whey is through the extraction of its proteins.

According to Sgarbieri (1996), whey proteins present high digestibility and excellent composition and bioavailability of essential amino acids – which are those necessary for humans and must be obtained by ingesting food.

Industrial processes also allow the extraction of lactose from whey in addition to the aforementioned proteins. The lactose according to Yang and Silva (1995), can be in the food industry (in candies, sauces, desserts, baked goods, etc.), as well as a raw material for lactose-based products (sweeteners, lactulose, lactitol, lactobionic acid, etc.), and also by the pharmaceutical industry (excipients for ointments and pills), among other uses.

At last, whey has been used by industry for bioconversion processes for the production of ethanol, lactic acid, biomass and also methane (Kosseva *et al*., 2008; Paneasar *et al*., 2007; Mawson; 1994)

Finally, it can be seen that the vast majority of products generated from whey industrialization is not sold to the final consumer being provided as ingredients for both the food and pharmaceutical industry (with the exception of concentrates, isolates, and hydrolysates of whey protein – commonly referred to as protein supplements for athletes; as well as dairy beverages and ricotta). Recent advances had shown that whey is also being used in other non-traditional industries, such as the furniture industry, as pointed out by Gao *et al.* (2011) who studied the creation of adhesives for wood panels made from whey protein.

4.2 Coordination and influence of the surrounding environments in the chain dynamics

Given that most of the products generated by the whey production chain are ingredients and/or inputs for other production chains (e.g.: lactose for the pharmaceutical industry), it is possible to infer that the industry has a strong coordination role in the chain, once it is the owner of the production processes. Thus, the coordination model can be seen as "via production" or "technology-push" (Lubic *et al*., 2013; Nemet, 2009; Zylbersztajn, 2005).

This coordination model begins from the premise of "pushing to market" products generated from the implementation of technologies in the industry, as emphasized by Lubic *et al.* (2005) and Herstattand and Lettl (2004), coordination through the market aims to market a particular technology, from an existing technology or in development. For the authors, this type of strategy often involves "trial and error", resource-intensive usage, and processes for market entry, requiring a proper marketing strategy, implementation of specific management strategies and a willingness to mitigate capabilities of current production.

In addition to the coordination model adopted in the production chain, it should be noted the importance of the surrounding environments for chain dynamics (Zylbersztajn, 2005), changes in the institutional and organizational environments for example affect the links and dynamics of the chain as a whole.

For the whey production chain, a change in the institutional environment that profoundly affected its dynamics was the resolution of the National Environment Council nº 430/2005, which deals with the parameters for the disposal of industrial effluents in wastewaters (BRAZIL, 2005) – already cited in this theoretical essay. This resolution has mobilized the industries and dairy plants to implement wastewater treatment plants and/or start to incorporate whey in manufacturing other products or even sell it for drying and concentration plants.

A second change in the institutional environment that affected the dynamics of the chain was the sanction of the Law nº 10.925 from July 23rd, 2004 (BRASIL, 2004), which reduced to 0 (zero) the PIS / PASEP and COFINS on imports and internal market commercialization of fertilizers, agricultural pesticides and others. Noteworthy is Article 1, section XI and XIII:

> Art. 1st: It is reduced to 0 (zero) the rates of PIS / PASEP and Contribution to Social Security Financing - COFINS on imports and on gross revenues from sales in the domestic market of:
>
> XI: pasteurized or processed liquid milk, ultra-pasteurized milk, powdered milk, whole milk, semi-skimmed or skimmed milk, fermented milk drinks and milk compounds and infant formulas, as defined according to specific legal provision intended for human consumption or used in industrialization products intended for human consumption;
>
> XIII: fresh fluid whey to be used in manufacturing products intended for human consumption.

Such change in the institutional environment had great impact on the dynamics of the chain, once with the tax exemption, manufacturers began to import larger quantities whey (especially after the sanction of the law - between 2004 and 2005) – as shown in Figure 4 – and because of that, started to buy smaller amounts of national whey.

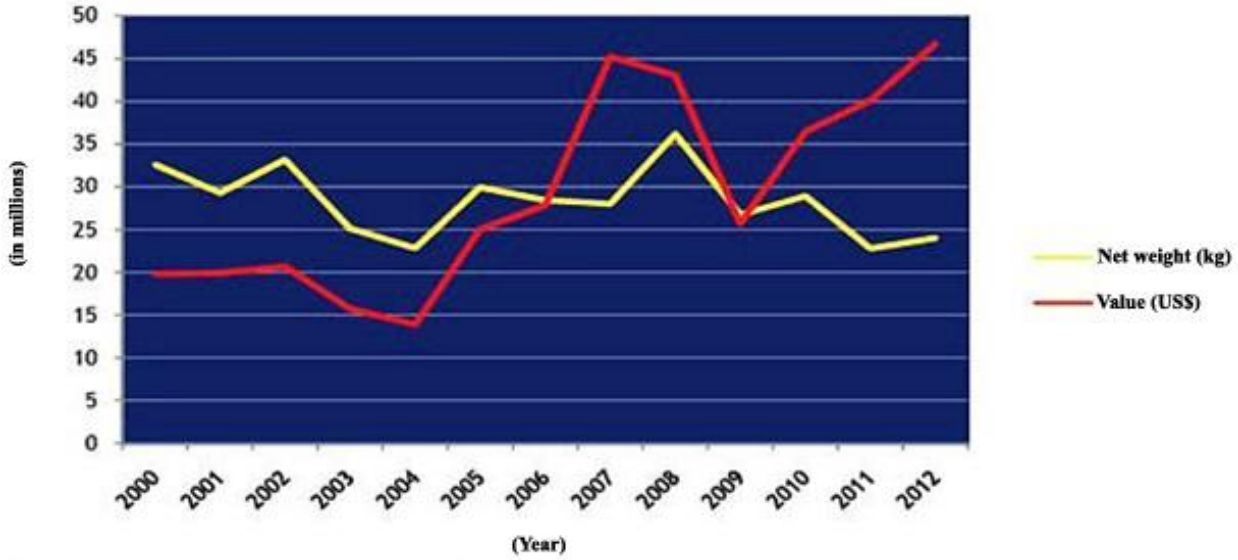

Figure 4. Brazilian whey imports from 2000 to 2012
Source: adapted from Pithan and Silva *et al.* (2013).

Regarding the organizational environment, it also impacts the whey production chain, a survey conducted by the authors of this essay (to be published) on the database Web of Science, found that Brazil is the second country with the highest number of publications on technology and processing whey, behind only the United States. Therefore, research centers, consultancy and R&D companies when developing processes and technologies that aim to enhances productivity and reduce costs, have an impact on industries, thus, affecting the dynamics of the chain.

As for consumer environment, considering that it is located upstream from the industry in the production chain, it was not in the scope of this theoretical essay to analyze it, however, as pointed out by Zylbersztajn e Neves (2000), one of the main issues of agri-food chains relates to the information asymmetry of between consumers and food producers. This asymmetry causes a market failure problem, since consumers tend not to reward high-quality products, not being able to distinguish them from lower quality products. Thus, the authors suggest that the productive agents must be aligned to the demands of consumers, and should provide much more complex relationships that go beyond those typical market transactions, where only prices and quantities are decisive variables.

5. CONCLUDING REMARKS

This theoretical essay aimed at describing the whey production chain focusing on links downstream of the industry. It was found that whey production chain starts within the dairy products production chain of, as its main raw material - the whey - is the waste (by-product) of the cheese-making process.

It was observed that Brazil has a great surplus of whey; which in turn is largely underutilized by the industry, which in many cases prefer to import it rather than purchase it nationally.

As for the industrialization processes, it was observed that the most elementary way to add value to the product is by using it fresh for animal feed, ricotta and dairy beverages manufacturing, however, such activities add little value when compared to more developed industrial processes such as separation of whey nutrients. Industrial processes such as ultrafiltration, reverse osmosis, membrane separation, spray drying, among other technologies allow the obtainment of products such as powdered lactose and its derived products; whey proteins and its derived products, and even ethanol.

It was noticed that the chain is strongly coordinated by the industry (technology-push) and that despite being incipient in a national level, it shows promising growth rates due to the low cost of acquisition of raw material and its abundant and widespread availability.

As for the dynamics, the main factors affecting the chain are changes in the institutional environment; such as laws and resolutions and changes in the organizational environment; as processes and technologies developed in research centers which can be incorporated into industrial processes in the chain.

For future research, it is suggested empirical studies that seek to verify the feasibility of the chain expansion in a national level (taking into account legal, budgetary, tributary, technological factors, among others); it is also suggested studies on the feasibility of establishing regional whey drying and concentration industry plants; studies that seek to raise econometric data on the Brazilian whey and whey-based products production and; also studies that focus the upstream of the industry in order to identify the distribution channels (wholesale and retail) and also the behavior and influence of the consumer environment.

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