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USE OF CHEESE WHEY BY FERMENTATION PROCESSES

Afram Domingos Silva de Meneses

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Abstract: Cheese whey is a residue originating from the dairy industry, and is a byproduct of great relevance given the high volume produced and its nutritional composition. Its disposal is a concern, considering the appeal in relation to environmental preservation. The present challenge is to develop technologies for the use of this residue with the production of compounds for various food applications and with high added value. Thus, this review aims to elucidate the advantages of using whey through fermentation processes. The work was carried out through a qualitative approach using consultations of national and international databases. The use of cheese whey in the preparation of products such as: dairy drinks, breads, cookies, value-added compounds, and others, emphasizes the aspects of sustainability and contributes positively to socioeconomic impacts.
Keywords: whey, cheese, fermentation.

INTRODUCTION

The constant growth of the Biotechnology field challenges the development of new processes for the use of agro-industrial waste, as it helps to obtain high value-added products and reduce costs. In industries where the product is obtained through fermentation, the choice of microorganisms resistant to process injuries is essential to guarantee product quality and higher yields and, consequently, greater profit for the sector (TAVARES, 2017).

Agro-industrial waste is generated in the processing of food, fibers, leather, wood, sugar and alcohol production, etc., and its production is generally seasonal, conditioned by the maturity of the crop or the supply of raw materials. Since this waste generally has a high concentration of organic material, its release into groundwater, surface water and soil can cause a significant decrease in the concentration of dissolved oxygen in this medium, the magnitude of which depends on the concentration of organic load and the quantity released, in addition to the flow rate of the receiving watercourse (MATOS, 2005).

A few decades ago, the process of transforming milk into dairy products did not take into consideration, the associated environmental and social impacts, constantly allowing the emergence of problems that are increasingly critical to the well-being of society, such as misery and poverty, unemployment, the devastation of productive soils, water and air pollution, among others (SANCHES, 1997).

Disposal in rivers, sewage and soil, animal feed, evaporation and drying, demineralization, extraction and refining of lactose, as well as ultrafiltration are common destinations given to whey (CARDI, 2007; SILVA et al., 2010).

Cheese whey was discovered approximately 3 thousand years ago and its use constitutes a major problem for the dairy industry due to the excess volumes in cheese processing, the high biochemical demand for oxygen and the presence mainly of lactose and proteins (BEAUSEJOUR et al., 1981; MAIORELLA & CASTILLO, 1984; PONSANO, 1992). During the development of technologies to improve milk industrialization processes, the possibility of industrially using cheese whey was observed, through some method of nutrient recovery instead of disposing of them directly (SINGH et al., 1983), or through a more critical examination, promoting its protein enrichment through its use in the production of unicellular proteins that also lead to a reduction in its pollutant capacity (MAHMOUD & KOSIKOWSKI, 1982). Such possibilities have attracted great attention from research centers, industries and government. Therefore, it is clear that the search for solutions for the use of whey from cheese production is an ongoing task, which challenges the sectors of industry, government, research and extension to contribute to the resolution or reduction of the problem, which may be not only nutritional but also economic.

Countries such as the United States, Australia, Canada, New Zealand and nations of the European Union process this dairy byproduct and its use in derivative products adds value to the dairy industry's production line (SILVA & BOLINI, 2006), representing a significant economic advantage for the dairy industry, due to the nutritional and functional properties of the whey and its components (HOMEM, 2003).

In Brazil, cheese production and consumption are common in many regions, especially in the Northeast, the states of Pernambuco, Rio Grande do Norte and Ceará (Cavalcante et al., 2007). According to the president of the Brazilian Association of Cheese Industries (ABIQ), cheese production reached approximately 1.1 million tons, resulting in the production of 110 thousand cubic meters of whey in 2013 (Scarcelli, 2015), a considerable part of which was generated by small and medium-sized industries that, avoiding the cost of treating this effluent and without effective supervision by the authorities, opt for partial use of this byproduct as animal feed, disposing of the surplus directly into rivers (MATOS, 2005; TONI et. al., 2012). Cheese whey is a byproduct of significant importance in the cheese industry, given the high volume produced and its nutritional composition. According to Juliano et al. (1987), the failure to rationally use whey resulting from cheese production in the dairy industry constitutes an uneconomic and even antisocial practice, due to the global food shortage and the pollution that this product causes to the environment. Cheese whey contains about 55% of the solids present in whole milk - and a large amount of lactose, mineral salts and water-soluble vitamins. It represents about 80 to 90% of the volume of milk used in the manufacture of cheese (CARLOS, 1997; ANDRADE and MARTINS, 2002; RAMADAN, 2005; BOSCHI, 2006). Although it received the status of medicinal agent in the 17th and 18th centuries, whey has been considered as a waste or effluent from dairy farms. At the end of the 20th century, the legislation of several countries determined the appropriate disposal of untreated whey. Beucler et al., 2005, still stated that most of the whey produced in the United States was used as fertilizer or as feed (BEUCLER et al., 2005; SMITHERS, 2008). The applications of whey are numerous: 50% in animal feed, 12% in industrial pastries and dairy products, 10% in ice cream, biscuits and bakery additives and 8% in margarines. Around 50% of milk solids go to whey along with almost 100% of lactose and around 20% of protein. Even so, due to the high levels of lactose and salts, only around 50% of the whey produced worldwide is used in the formulation of products and the rest is treated as waste (FRAZÃO, 2001).

Among the various whey constituents, lactose (in concentrations of 5-6% weight/volume) is the main one responsible for the high biochemical demand, despite this it has potential as a substrate for a variety of microorganisms such as: *Saccharomyces thermophilus, Lactoacillus bulgarius, Candida pseudotropicalis, Kluyveromyces marxianus, Kluyveromyces lactis* and others. Several researchers have used this potential to obtain yeast extracts ("Single cell protein") as a dietary supplement for animals and humans and to obtain the enzyme β-galactosidase (lactase) of great interest to the food industry, to obtain ethanol (DZIEZAK, 1984; SISO, 1996; BAROLI et al., 2001; REVILLION et al., 2003; GHALY & KAMAL, 2004; LONGUI et al., 2004 and TAVARES, 2017) and to obtain high added value organic compounds such as isoamyl alcohol, 2-phenyl ethyl alcohol, isobutyric acid, 2-3-butanediol, 3-hydroxy-2-butanone (acetoin), 2-phenylethyl acetate, isobutanol and 2-phenylethyl isobutyrate (FABRE, 1995; JIANG, 1995; MENESES, 2009).

Basically, after the fermentation process, whey, which initially presents the characteristic of being an energy product due to its high lactose content, would have a high protein content, resulting from the use of its lactose by microorganisms, which characterizes it as a protein-calorie product (BEAUSEJOUR et al., 1981), and possibly with lower polluting powers given by the reduction of BOD (POSANO, 1992).

In view of the above, the purpose of this work is to present the advantages of using cheese whey and evaluate its potential for obtaining compounds through fermentation processes.

METHODOLOGY

This work is a qualitative research focused on describing the use of cheese whey to obtain compounds through fermentation processes. Research was carried out through consultations in national and international databases, including books, periodicals, government information, magazines, newsletters, dissertations and published theses.

BIBLIOGRAPHICAL REVIEW

Cheese Whey

Whey is a byproduct of the cheese industry, also known as milk whey. It is an opaque, yellow-green liquid obtained after the precipitation of casein from milk during cheese production. Its flavor is slightly acidic or sweet and its composition depends on the type and process of cheese production. This product represents 85-95% of the volume of milk and contains approximately 55% of its nutrients, represented by water-soluble proteins, mainly albumins and globulins, salts, fat and lactose (MORR et al., 1976, SISO, 1996, ZUÑICA et al., 2002: PACHECO et al., 2005; CHAVES et al., 2010). The basic composition of cheese whey obtained in the production of "coalho-type" cheese is presented in Table 1.

Physical-Chemical Components	Average Result (Standard Deviation)
pH	6,34 ± 0,54
Acidity in Dornic degrees (°D)	11,00 ± 1,16
Fat (%)	0,33 ± 0,06
Lactose (%)	4,25 ± 0,05
Total dry extract (%)	6,43 ± 0,08
Mineral salts (%)	0,60 ± 0,01
Protein (%)	1,25 ± 0,06
Defatted dry extract (%)	6,10 ± 0,11
Moisture (%)	93,57 ± 0,08

Table 1: Physicochemical composition of whey from "Coalho Type" cheese

Source: Barbosa *et al.,* (2010)

An important point is the fact that, in Brazil, data on the availability of cheese whey are imprecise. However, it is known for sure that around 35% of milk production in the country is used to make cheese (CARVALHO et al., 2005). This imprecision is due to production by small companies that, avoiding the cost of treatment and without effective supervision by the authorities, opt for partial use of this byproduct in animal feed, with the surplus being discarded (ORCHARD, 1972; VOORBERGEN & ZWANENBERG, 2002).

In the state of Sergipe, it is estimated that whey production is approximately 5 tons per week, however, there is no type of treatment for the whey from the various dairy production lines. However, it is essential to present economic and environmental feasibility studies, covering the use of whey constituents, with a view to adding value to various products, due to the high economic value of proteins, as well as reducing the environmental impact caused by the high organic load present in this residue (MENEZES, 2007).

For decades, sweet whey has been known as a product with high nutritional value, containing 1.0% high nutritional value protein, 0.5% lactose, 0.7% mineral salts, 0.3% fat (FITZSIMONS et al., 2006) and several types of vitamins as shown in Table 5.

Vitamins	Quantity (mg/Kg)
Thiamine	0,31
Folic acid	0,07
Niacin	1,18
Riboflavin	0,16
Choline	108,00
Pantothenic acid	3,94
Biotin	1,50
Cobalamin	0,15
Pyridoxine	20,00

Table 2: Serum vitamin levels

Source: ABREU (2000).

With the disposal of whey as waste, it is estimated that approximately 48 thousand tons of proteins, 24 thousand tons of lactose, 33.6 thousand tons of mineral salts, 14.4 thousand tons of fat and 5.76 tons of riboflavin are lost per year (FAO, 2010).

Today, the development of markets using cheese whey and whey fractions as ingredients in foodstuffs for human and animal consumption has transformed the byproduct into a valuable product for the dairy and cheese industries.

The composition and type of whey produced in the dairy industry vary depending on the technological processes employed, the milk used and the type of cheese manufactured (FURTADO & POMBO, 1988 and MARWAHA & KENNEDY, 1988). According to the production method, whey can be classified as sweet whey or acid whey. In Brazil, whey production consists almost exclusively of sweet whey, which is produced during the production of coalho cheese, mozzarella, cheese, Minas Frescal cheese, half-cured cheese and others through the enzymatic coagulation of milk proteins. The pH of sweet whey can vary between 5.2 and 6.7. Acid whey is obtained by the precipitation of milk casein, through lactic acid and hydrochloric acid, during the production of ricotta and cream cheese (ABREU, 2000). The composition of acid and sweet whey is presented in Table 6.

Components	Sweet serum (%)	Acid serum (%)
Water	93 – 94	94 – 95
Total Solids	6 – 7	5 – 6
Lactose	4,5 – 5	3,8 - 4,2
Protein (N x 6,38)	0,8 – 1	0,6 – 1
Non-protein nitrogen (Total N)	22	27
Lactic acid	0,1 - 0,2	0,7 - 0,8
Ashes	0,5 - 0,7	0,7 - 0,8

Table 3: Composition of sweet whey and acid whey

Source: HARPER (1998).

Whey can be used to obtain products such as whey powder, milk drinks, ricotta, protein concentrate, baby food formulations, yogurt, dulce de leche, value-added compounds and others; in animal feed in liquid, condensed or dry form; and in sewage disposal after adequate treatment (CARMINATTI, 2001). The permeate composed of lactose is generally discarded. The retentate is formed mainly by 85% proteins and 15% lactose. Whey proteins represent 20% of milk proteins, the most abundant being: β-lactoglobulin (50%), α-lactalbumin (12%), immunoglobulins (10%), serum albumin (5%) and peptones (0.23%) (SISO, 1996).

The high lactose content of whey ensures that it can be used as a carbon source by certain microorganisms, such as: *Saccharomyces thermophillus, Lactobacillus bulgarius, Kluyveromyces lactis* and others (SILVA & CASTRO-GOMEZ, 1995).

Microbiology of Cheese Whey

A study of the history of the use of microorganisms for consumption shows that they are sources of enzymes in the food industry; producers of nutrients; and are used directly, in microbial biomass, as food material (BRANDÃO, 1987). In relation to dairy products, the importance of microorganisms is due to the fact that they are the agents responsible for the flavors, aromas, physical defects and desirable characteristics that appear during the preparation of these products (TRAVASSOS, 1999).

Whey is an excellent substrate for microbial growth due to its nutritional composition. Raw whey generally contains microorganisms of the following genera: *Staphylococcus ssp, Streptococcus ssp, Pseudomonas ssp, Acinetobacter ssp, Flavobacterium ssp, Enterobacter ssp, Klebsiella ssp, Aerobacter ssp, Escherichia ssp, Serratia ssp, Alcaligenes ssp, Lactobacillus ssp, Clostridium ssp, Bacillus ssp, Penicillium ssp* (TRAVASSOS, 1999). On the other hand, it can serve as a nutrient medium for the growth of microorganisms such as: *Lactobacillus bulgaris, Lactobacilus casei, Lactobacillus helveticus, Streptococcus thermophilus, Lactobacillus acidophilus and Kluyveromices lactis.* (SCIENKIEWICH & RIEDEL, 1990; SEVERO, 1995 e ABREU, 2000).

Although the yeast *Saccharomyces cerevisiae* is the microorganism traditionally used in alcoholic fermentation, it is not capable of metabolizing the lactose present in the serum, due to the absence of the enzymes of galactosidase, which hydrolyzes this sugar into glucose and galactose, and permease, which allows the entry of lactose into the cells (SISO, 1996).

Many species of yeasts of the genus *Kluyveromyces* such as *K. lactis, K. marxianus, K. fragilis* have demonstrated the capacity to ferment lactose present in cheese whey, and this is the microorganism most used to obtain ethanol from this residue (SISO, 1996; BELEM & LEE, 1999; ARAÚJO, 2001; SANTIAGO et al., 2004; SILVEIRA et al., 2005 and KARGI & OZMIHEI, 2006).

Use of Cheese Whey

In recent years, dairy industries have shown increasing interest in using whey residue from cheese production, mainly because it is a residue with high nutritional value and is highly polluting. Of the components present in whey, lactose and soluble proteins are the most important, which give the residue a high biochemical oxygen demand. When whey is released into waterways, it causes an enormous polluting effect (approximately 100 times greater than that of domestic sewage) due to the consumption of oxygen that reduces aquatic life (MIRANDA et al., 2005). Due to the high quantity of organic substances, represented mainly by lactose (approximately 70% of total solids) and proteins (approximately 20% of total solids), whey imposes a Biochemical Oxygen Demand – BOD of between 30,000 and 60,000 mg of O2/L and a Chemical Oxygen Demand – COD of around 50,000 mg of O2/L, depending on the specific processing used in the production of the cheese and the lactose content. Comparatively, each 5,000 liters of cheese whey in a sewage treatment plant is equivalent to treating the waste of 2,000 people (PONSANO, 1995; REVILLION, 2000; REVILLION, 2002 and ANDRADE & MARTINS, 2002). The use of whey in the food industry has been studied by several authors, from its use as a raw material in the preparation of dairy beverages to the use of modern technologies to obtain specific and/or new products to be used mainly by the food industry (COTTON, 1985; CHIAPPINI et al., 1995; FERREIRA, 1997; FONSECA, 2008; PELEGRINI and CARRASQUEIRA, 2008 and MENESES, 2009). This residue has been increasingly used in the preparation of new products, either as a simple substitute for water or as an ingredient with rheological or nutritional functionality (MENEZES et al., 2007). The increase in whey production, the implementation of environmental protection laws, and the recognition that the use of liquid whey for animal feed is only viable are factors that have encouraged the industry to commercialize this product. Once the industrialization of cheese whey has been optimized, the advantages will be the following:

- Protection of the environment;
- Development of products with greater physiological and nutritional value, including products for pharmaceutical applications;
- Increased sales, through increased production and the introduction of new products;
- Optimization of the use of dairy solids, adding better use to the raw material and the value of the available basic components;
- Improved yield;
- Reduction in imports of dairy products.

However, for the rational use of whey, it is necessary to determine its microbiological and physical-chemical quality profile, which will indicate which processes will be most appropriate and which products can be obtained from this raw material (FERREIRA, 1997 and FONSECA, 2008). One solution would be to implement cooperatives, but this requires greater clarification and encouragement to make greater use of this byproduct. In Brazil, the main advantage of using whey in its liquid form is that it is a low-cost ingredient, containing 95% water. In countries such as the United States, its value increases due to the 5% of nutrients that can be exploited with much higher added value, as a healthy ingredient for athletes, appetite suppressant and with pharmaceutical properties, among other benefits (CARVALHO, 2005). In short, it can be inferred that whey, before being considered merely as a component of dairy industry effluents, can and must be used (MATOS, 2005). It is known that products obtained from whey normally reach a high price on the market and have functions, mainly, of increasing the nutritional value, in addition to conferring desirable rheological characteristics to the products in which they serve efficiently as ingredients (FRAZÃO, 2001). The forms of using cheese whey can be divided according to the type of processing used as non-fermentative and fermentative.

Use of Whey by Non-Fermentative Processes

Regarding the use of whey and its components for more noble purposes and thus having an alternative to minimize the environmental impact and take advantage of the nutritional properties of cheese whey, it is possible to use it in the production of new food products or add value to existing ones. Thus, a series of uses for whey and its products can be cited, such as: whey powder and concentrate, which have several uses such as protein concentrate and protein isolates, lactose and riboflavin (ABREU, 2000).

Santos et al., (2016) highlighted that 50% of the world's whey production is processed and transformed into various food products, and of this total, almost half is used directly in liquid form.

In the Middle Ages, whey was used in pharmaceutical drugs as a component of ointments for burns, as a skin balm or as a neutralizing portion for hair, but it was rarely used in human food (KOSIKOWSKI, 1979).

The use of cheese whey became widespread in the mid-19th century in Western Europe, with the creation of more than 400 "whey houses". Around 1940, in Central Europe, it was used to treat dyspepsia, uremia, gout, anemia, arthritis, liver disease and even tuberculosis, when the ingestion of approximately 1,500 g/day of whey was recommended (HOLSINGER et al., 1974).

According to Homem (2003), the finished product resulting from the processing of cheese whey can be used in several industrial sectors. The pharmaceutical industry uses fractionated proteins of high biological, dietary and physiological value extracted from processed whey. The cosmetics industry takes advantage of the phosphorus-lipid components of whey, which are highly moisturizing and highly absorbed by the skin, with excellent saponifying properties. The chemical industry uses whey to produce biodegradable plastics, which are manufactured from dairy component substances also extracted from cheese whey (HOMEM, 2003). The application of cheese whey products for food is divided according to their destination, whether animal or human. In the animal feed sector, whey and derivatives are used to replace powdered milk as a mineral supplement in feed and molasses, with the use of calcium phosphate, in ammonium lactate for feed and in the production of yeast, with biomass, through the use of lactose or whey permeate. The use of whey in human nutrition began in 2002, with the launch of dairy drinks (SENA, 2007). Whey products are intended for the manufacture of fine cheeses, creams and whey powder, whose market and application are favorable for crystallized products with a maximum of 1.25% fat. The pH of the whey powder is also very important, and must be on average 6.1 - 6.3, for good marketing (HOMEM, 2003). Whey can also be used as an additive or food supplement in reconstituted milk, infant diets, ice cream, beverages, processed meats and, due to its gelling properties, it can be used advantageously to replace egg whites (BATISTA, 2008). Ciabotti et al. (2009) used the residue by associating it with soy extract as an alternative for enriching soy proteins, which are deficient in sulfur amino acids such as methionine and cysteine, since whey has them in high concentrations. Diniz et al. (2012) used whey as a carbon source for enzyme production. Pelegrine and Carrasqueira (2008) associated acid whey with the function of enhancing the flavor of creamy salad dressings, retaining water, emulsifying and providing calcium, and sweet whey was associated with various applications in bakery products, snacks, ice cream and dairy desserts. Research at Embrapa (2012) investigated the use of whey as a functional ingredient capable of acting as an adjuvant in treatments for hypertension and cardiovascular problems.

Another study also developed by Embrapa (2011) proposes the addition of whey protein isolate to polished white rice flour, which will give rise to snacks. Methods such as ultrafiltration have been used to separate proteins, the most "noble" components of whey, from other constituents (lactose and minerals).

During the ultrafiltration process, two products are produced (Figure 1): the concentrate or retentate, represented by the material retained by the membrane, and the permeate, the name given to the material that passes through the membrane (DOMINGUES et al., 2000). Currently, most of the whey worldwide is processed by ultrafiltration, obtaining approximately 5 x 108 kg/year of protein concentrate (PINTADO et al., 2017).

The whey permeates obtained after ultrafiltration can be used for various purposes, such as animal feed, production of lactose, galactose, glucose, alcohol, lactic acid or as a constituent in various pharmaceutical products and even cosmetics. To this end, pasteurization, concentration and fermentation are primary processes used in the preparation of whey aiming at its best use (ABREU, 2000).

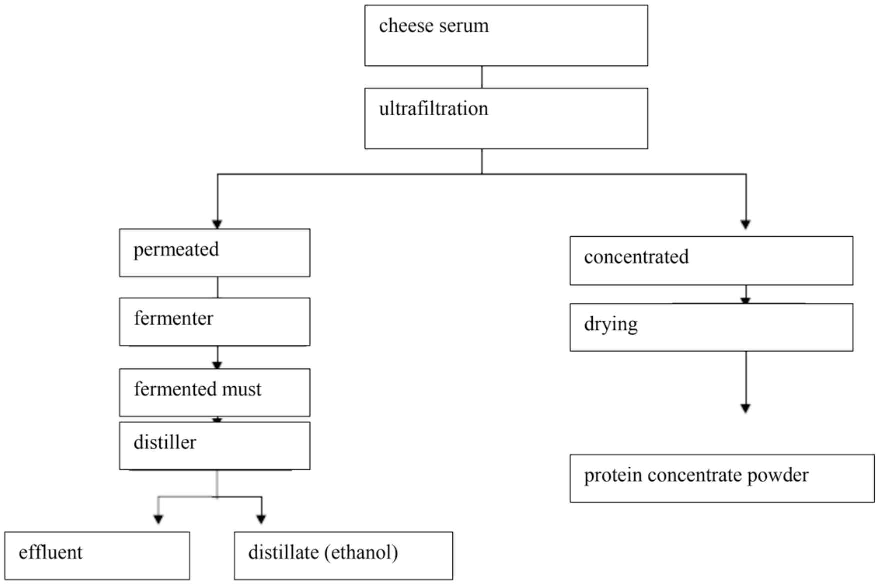

Figure 1: Diagram of the full valorization of cheese whey (Source: DOMINGUES et al., 2010).

Whey protein concentrates have desirable functional characteristics for the food industry– good solubility, viscosity, stabilizing, emulsifying, foaming, gelling capacity and good water absorption (MATHUR & SHAHANI, 1979). Thus, these proteins have found a number of applications in the food industry, including dehydrated soups, salad dressings, baby, dietetic and geriatric foods, ice cream, cheese, bakery products, confectionery, yogurt, meats, dairy drinks and as a food supplement (HIDALGO & CAMPER, 1977). Andrade and Martins (2002) studied the influence of the addition of sweet potato starch on the viscosity of cheese whey permeate and observed the good potential of these for use as a thickener in dairy drinks. Concentrated or dry whey can be used as an additive in various foodstuffs intended for human consumption. The addition of powdered whey at levels of 0.7 to 1.5% provided the yogurt with better viscosity, shorter coagulation time, better firmness and did not present syneresis. The product with added whey is more nutritious and has a higher protein and vitamin content (CRISTIANINI & ROIG, 1987). The addition of ultrafiltered whey protein concentrate at levels of 5 and 10% in the production of cream cheese results in an increase in yield of around 10 and 20%, respectively, with no difference in the acceptance of the product from a sensory point of view (CONDACK et al., 1994).

According to Singleton (1972), ice cream is the dairy product that uses the most whey. The use of cheese whey as a substitute for powdered milk in ice cream formulations is a way of adding value to this residue and results in a reduction in its fat content, with a sensory acceptance of 88.4% (PADILHA et al., 2006). This acceptance was confirmed by Silva and Bolini (2006) when evaluating ice cream formulated with acid whey product. Bezerra et al. (2005) partially replaced water used in bread production with cheese whey obtained by enzymatic coagulation, resulting in improved dough and crumb development, softer texture and a marked improvement in the color of the rind. Vargas et al. (1983) conducted an experiment replacing rice cooking water with whey from fresh whole cheese, reducing the degree of malnutrition in a group of children.

Whey has also been used in the production of candies and chocolates to provide caramel aroma and color, which occurs through the reaction of proteins with lactose and dextrose in the presence of high temperatures. According to Neurath (1996), the β-lactoglobulin protein, present in abundance in whey, can actively intervene in preventing the transmission of the HIV virus (BATISTA, 2008).

It is therefore clear that whey protein ingredients are used for a variety of functional applications in the food industry. Some applications are presented in Table 4.

Application	References
Dairy Drinks	Caldeira *et al.*, (2010);
Edible films	Yoshida; Antunes (2009); Ramos *et al.*, (2013)
Cookies, cake and tofu	Zavareze *et al.*, (2010); Guimarães (2011), Ciabotti *et al.*, 2009
Product enrichment (breakfast cereals, yogurt, dulce de leche, ice cream, bread, extruded products, beverages)	Zambrano *et al.*, (2012); Silva *et al.*, (2011); Silva *et al.*, (2004); Rocha *et al.*, (2012), Silva; Bolini (2006); Valduga *et al.*, (2006), Embrapa (2011); Sinha *et al.*, (2007).
Ricotta	Egito *et al.*, (2007)
Fermentation medium for bacteria and fungi	Diniz *et al.*, (2012); Barbosa *et al.*, (2010)

Table 4: Application of whey in the food industry

In addition to these applications, whey has been used to obtain various compounds through fermentation processes, as will be reported below.

Use of Whey through Fermentation Processes

Fermented products have been known for millennia. There are records of wine production in Syria in 3500 BC, and of beer and bread in the fifth Egyptian dynasty in 2400 BC, but the first reference dates back to 7000 BC with the production of beer in Sumeria (BROCK et al., 1994). It was only in the 19th century that the biological nature of the agents responsible for the fermentation processes was recognized, which were identified as yeasts (WALKER, 1998).

Whey can be fermented directly or after fractionation. Natural whey, permeate resulting from ultrafiltration and molasses resulting from the crystallization of lactose are possible substrates for fermentation. The use of whey in the manufacture of products by fermentation generally depends on the availability of a safe microorganism that converts lactose into the desired substance and the viability of the cost of the source of the carbohydrate to be fermented (TORRES, 1988). Whey can also be fermented as an alternative for producing biogas and biomass, which can be used as an energy source (PONSANO and CASTRO-GOMEZ, 1995).

Several studies have been carried out to verify the use of whey and whey permeate as a substrate for microorganisms to ferment lactose and obtain various products, such as bread yeast, galactose, ethanol and mainly lactic acid by Lactobacillus helveticus. Bosnea et al., (2008) used a mixture of cultures of *Kluyveromyces marxianus, Lactobacillus delbrueckii ssp bulgaricus and Lactobacillus helveticus* for the production of lactic acid from cheese whey. The bioutilization of cheese whey for the production of lactic acid was studied by Panesar (2007).

One of these major areas of research is the fermentation of lactose by yeast (Abreu, 2000), with the baby food industry being a potential market (Kennedy, 1985), as well as animal feed, where yeast growth can be used as a high-quality protein supplement. Although the production of lactose from whey has increased steadily since the 1940s, the quantities of purified lactose produced worldwide have used only 5% of the available whey (SISO, 1996).

Alternative uses of lactose have been proposed based on the direct fermentation of this sugar or fermentation of the sugars obtained from its hydrolysis, glucose and galactose. Processes based on fermentation through microbial cells have been considered the most profitable alternative for the transformation of cheese whey (SISO, 1996).

In the literature, several yeasts are studied, seeking the best efficiency during these processes. Examples of these yeasts are: *Kluyveromyces fragilis* (Dragone et al., 2011), Kluyveromyces lactis (Coutinho et al., 2009), Kluyveromyces marxianus (Coutinho et al., 2009; Guimarães et al., 2010; Koushki et al., 2012), Saccharomyces cerevisiae (Guimarães et al., 2010), *Saccharomyces fragilis* (Coutinho, 2009), *Candida pseudotropicalis* (Guimarães et al., 2010), Candida kefyr (Guimarães et al., 2010; Koushki et al., 2012). *Vananuvat & Kinsella* (1975), Gilliand & Stewart (1980), Beausejour et al., (1981), Shay & Wegner (1986) and Silva & Castro-Gomez (1995) fermented cheese whey using the yeast Kluyveromyces fragilis and obtained products with protein concentrations equal to 58%, 57%, 57.4%, 43.8% and 39.6%, respectively (HERNAN-GOMEZ et al., 2000). Abreu et al., (1976), Mahmoud (1980) and Silva & Henan-Gomez (2000) improved the protein quality of cheese whey through fermentation using *Kluyveromyces fragilis.*

Cheese whey fermentation can be used to produce the enzyme β-galactosidase, whose versatility as a microorganism of industrial interest has been widely illustrated by the diversity of industrial processes reported in the literature. Bales & Castilho (1979); Grubb & Mawson (1993); Mahoney et al., (1997); Rech (1998); Martins et al., (1998); Belém & Lee (1999); Ayub et al., (2000); Furlan et al., (2001);

Abad et al., (2001); Ribeiro et al., (2004); Marquez et al., (2004) and Barbosa & Araújo (2007) used cheese whey to produce the enzyme β-galactosidase using yeast: *K. marxianus*.

The production of alcohol through the fermentation of cheese whey has been stimulated by the growing global need for energy, in addition to representing a simple way of treating and disposing of large quantities of cheese whey produced by the industry (KOSIKOWSKI, 1979). However, the use of cheese whey through lactose fermentation to obtain ethanol has received special attention in recent decades and several large-scale processes have been developed. Several distilleries have commercially produced ethanol from whey (SISO, 1996). Ozmihci et al., (2006) studied the operational effects on alcohol production parameters using cheese whey. Ponsanno (1992) and Araújo et al., (2005) produced 14 g/L, Ferreira (2003), produced 20 g/L, Zafar et al (2006) obtained 2.1 g/L and Ozmihci et al., (2007) obtained a 3% ethanol content from cheese whey using the yeast: *K. marxianus*.

Although the yeast *Saccharomyces cerevisiae* does not metabolize lactose, several approaches for the fermentation of lactose by this yeast have emerged in recent years. Domingues et al., (1999) obtained ethanol from cheese whey permeate (containing 50 g/L of lactose) using S. cerevisiae. Andrade et al., (2005) reported the fermentation of 90 g of cheese whey with the yeast S. cerevisiae and obtained an alcoholic production of 3.66 g/L. Suzart et al., (2007) produced 335 mL of brandy from 20 L of cheese whey inoculated with S. cerevisiae. Lopes et al., (2015) obtained alcohol with a GL content of 5.3º from 100 mL of cheese whey after inoculation with *S. cerevisiae.*

The fermentation of cheese whey using *Escherichia coli B. ATCC* 11303, recombinant KO11, has allowed the production of ethanol under laboratory conditions with promising results, enabling better use of this byproduct, although total conversion depends on appropriate supplementation (LEITE, 1996). Using E. coli strains using cheese whey, Guimarães et al., (2000) produced ethanol with a yield of 96%.

Whey can also be used through its deproteinization to produce lactic bacteria and, through continuous fermentation of this whey using *Penicillium cyclopium*, mushrooms are produced (SILVA & CASTRO-GOMEZ, 1995).

Several technological processes have been developed for the fermentative conversion of whey into different beverages such as wine, fermented beverages containing fruit concentrates, champagne, and beer (SEVERO 1995). The production of beverages and soft drinks from whole whey has been developed in several countries, such as the United States, Japan, and Germany, by adding aroma, fruit juice, kefir grains, yogurt, skim milk, and stabilizer to the whey (HOLSINGER et al., 1974; GODINA, 1974; MANN, 1976). Shirai et al. (1992) produced a fermented beverage using two different cultures from soybeans, oat flour, and powdered cheese whey, with sugar, calcium, and flavorings as additives (ABREU, 2000).

In Brazil, the production of dairy beverages is one of the main options for using whey, and the most commercialized are fermented beverages, with sensory characteristics similar to yogurt, and non-fermented dairy beverages. However, the use of this byproduct reaches only 15% of the total whey produced (NEVES, 2001 and NAKAMAE, 2004). Lacerda et al., (2007) prepared dairy beverages using continuous and discontinuous fermentation, using as substrate, different concentrations of cheese whey inoculated with commercial lyophilized cultures of Streptococcus thermophilus and Lactobacillus bulgaricus. Shene et al., (2008) extracted exopolysaccharides from cheese whey using *Streptococcus thermophilus*. Teixeira et al., (2006) extracted dextrose and fructose from cheese whey using Leuconostoc mesenteroides. Papavasiliou et al., (2008) produced a milk beverage with a concentration of 2.5 g/L using *K. fragilis*. Soave et al., (2007) studied the influence of cheese whey on the shelf life of milk beverages, observing that the whey provided an increase in titratable acidity, therefore a shorter fermentation time and a longer shelf life. Bonassi et al., (2001) evaluated the physical and chemical characteristics of milk beverages fermented by *S. thermophilus* and L. bulgaricus and prepared with whey. Tortelli et al., (2002) developed a milk beverage by fermentation process, using S. thermophilus and L. bulgaricus, whose shelf life defined based on physicochemical, microbiological and sensory analyses was 10 days.

Torres et al. (1989) developed a technologically and economically viable beverage using pasteurized mozzarella cheese whey with added sugar, stabilizer and flavoring (apple, strawberry, pineapple, lemon and pear flavors), obtaining a nutritional value above expectations. According to Ostlie et al. (2004), the global trend observed in the last twenty years is the use of lactic cultures in the food and pharmaceutical areas.

As a result, several health benefits have been associated with the consumption of fermented milk-based products (LACERDA, 2007 and DAVE & SHAH, 1997). It is necessary to isolate and select lactic bacteria specific to the ecological conditions of Brazil, as well as to develop the technology for producing these cultures. Several authors have suggested the use of cheese whey as a basic constituent of culture media for the large-scale production of lactic bacteria (PAOLUCCI, 1991).

The permeate resulting from the whey ultrafiltration process can be used in fermentation processes for the production of organic acids: lactic, acetic, propionic and citric (YANG, 1995). In the food industry, propionic acid and its salts are used as preservatives in foods with high moisture content, being incorporated to prevent the growth of mold in breads and cakes, and on the surface of cheeses and meats. (COLOMBAM, ROGER & BOYAVAL, 1993). Neves *et al.,* (1999) produced propionic acid through fermentative processes using *Propionibacterium freudenreichii* cultivated in cheese whey permeate. Plessas et al., (2008) produced lactic acid using a mixed culture of *kluyveromyces* and *Lactobacillus.*

Recently, several agro-industrial residues have been used as substrates for the production of enzymes. Nascimento & Martins (2006) and Carvalho et al., (2007) used whey for the production of proteases by Bacillus sp. Other products such as xanthan gum and water-soluble soybean extract have been produced from whey-based culture media using the microorganism Xanthomonas campestris (SCHINATTO et al., 2001; BENEDET et al., 1999).

After the fermentation process, the cheese whey, which initially presents the characteristic of being an energy product (due to its high lactose content), would have a high protein content, resulting from the use of its lactose by microorganisms. Belem et al., (1999) used K. marxianus and obtained a biomass with a low sugar content. This fact characterizes it as a protein-caloric product and possibly with a lower polluting potential due to the reduction of BOD (SILVA & CASTRO-GOMEZ, 1995). Ghaly et al. (2004) developed an aerobic fermentation with K. fragilis, thus reducing the pollution potential of the proteins contained in whey. Pastore et al. (2006) selected Kluyveromyces among other pectinolytic microorganisms for the production of fruity aromas from waste from agroindustries. Teixeira et al. (2008) characterized volatile compounds produced in the alcoholic fermentation of cheese whey.

The production of these volatile compounds varies according to chemical, physical and biological factors. Cultivation conditions, such as medium composition (source of carbon, nitrogen and other elements), pH, fermentation time, incubation temperature, agitation and aeration, were identified as determining factors of the type and quantity of aroma compounds produced, in addition to the strain of the microorganism (SARIASLANI & ROSAZZA, 1984; ARMSTRONG & BROWN, 1994; GATFIELD, 1988; SCHARPF et al., 1992; JANSSENS et al., 1992 and WELSH, 1995). These variables may be involved in the physiological mechanisms that influence the types and quantities of products formed by the microorganisms (SARIASLANI & ROSAZZA, 1984). The first reports of aroma-producing microorganisms date back to 1970, when Tahara et al., (1975) evaluated the production of aromas by Sporobolomyces odorus. Fabre et al., (1995) cultivated Kluyveromyces marxianus in a defined medium and observed the formation of a strong banana aroma, which was probably due to the production of isoamyl acetate. Drawert & Barton (1978) reported the biosynthesis process of monoterpenes (citronellol, linalool and geraniol) from glucose by the yeast Kluyveromyces lactis. Jiang (1995), in studies of the volatiles produced by K. lactis in liquid medium under agitation, identified the predominant compounds: isoamyl alcohol, 2-phenylethyl alcohol, 2-3-butanediol, 3-hydroxy-2-butanone (acetoin), 2-phenylethyl acetate, isobutanol and 2-phenylethyl isobutyrate. Meneses, et al., 2009, obtained, after 30-hour fermentation, the compounds 2-hexadecenal and octadecanoic acid, with high added value.

FINAL CONSIDERATIONS

Cheese whey, which was once discarded from dairy industries or underutilized, has been greatly valued with a series of discoveries about its functional properties. This has been one of the greatest challenges for biotechnology, developing techniques for the industrial use of agro-industrial waste that is considered a serious problem for the environment, at a time of advances in national and global sustainability policies.

The compounds obtained through fermentation processes aimed at using cheese whey can be used in the preparation of food products such as cakes, cookies, ice cream, bread, dairy drinks, etc., in the development of edible films and coatings for packaging food and in antitumor activities.

In short, the 21st century is mainly concerned with the environment and the sustainability of the planet and thus, through the use of cheese whey, Biotechnology contributes to improving food security and the environment, with a positive emphasis on socioeconomic impacts.

REFERENCES

ABIQ. ASSOCIAÇÃO BRASILEIRA DAS INDÚSTRIAS DE QUEIJO. Controle da poluição em indústria de queijo. In: **Leite e derivados**, n. 99, mar/abr. p. 64-65, 2013.

ABREU, L. R. **Tecnologia de leite e derivados.** 1 ed. Lavras: UFLA/FAEPE, 2000. **Agricultural Biological Chemistry**, v. 39, n. 1, p. 281-282, 1975.

ANDRADE, R. L. P.; MARTINS, J.F.P Influencia da adição de féculas de batata doce sobre a viscosidade do permeado de soro de queijo. **Ciência e Tecnologia de alimentos**, Campinas, v.22, n.3, p.249/253, set/dez, 2002.

AQUINO, L.C.L; RAMALHO, S.A. Estudo cinético do processo de fermentação alcoólica a partir do soro do queijo, Anais do XVII Congresso Brasileiro de Engenharia Química. Recife, PE, 2008.

ARAÚJO, J. M. A. **Química de alimentos**: teoria e prática. 3ª ed. Viçosa: UFV, 2004.

BANAT, I. M.; NIGAM, P.; MARCHANT, R. the isolation of thermotolerant fermentative yeast capable of growth at 520C and ethanol production at 480C e 500C. **World Journal of Microbiology and Biotechnology.** V.8, p.259-263, 1992.

BEHRENS, J. H. (1999), Fermentação láctica de leite de soja por culturas probióticas comerciais: monitoramento do processo fermentativo e avaliação sensorial de aceitação. **Dissertação de Mestrado**, 109p., Universidade Estadual de Campinas, Campinas, Brasil.

BELEM, M. A. F.; LEE, B. H. oligossacharides extracted from cell walls of Kluyveromyces marxianus grow on whey. **Biotechnol. Technol.** V. 12 (3), p. 229-233, 1998.

BEZERRA, A.K.N.A; SOUZA, J.R.M. **Utilização de soro de queijo na elaboração de pães**. Unicentro, Guarapuava, 2005.

BOBBIO, P. A.; BOBBIO, F. O. **Química do processamento de alimentos**. 2. ed. São Paulo: Varela, 1995.

BONEKAMP, F. J. & OOSTEROM, J. On the safety of *Kluyveromyces lactis* – a review. **Applied Microbiology and Biotechnology**, v. 41, p. 1-3, 1994.

BRAGA, L.N. **Questão de Opinião**, 03 de maio de 2017 às 16:25

BRANCHAT, G. R.; CABISCOL, E.; TAMARIT, J.; ROS, J. Oxidative damage to specific proteins in replicative and chronological-aged *Saccharomyces cerevisiae*. **The Journal of Biological Chemistry**, v. 279, n. 30, p. 31983-31989, 2004.

BROCK, T. D.; MADIGAN, M.T.; MARTINKO, J.M. Industrial Microbiology In: **Biology of Microorganisms**. New Jersey: Prentice-hall, 7ª ed., p. 361-396, 1994.

CAMPOS, L. L. Obtenção e caracterização de mutantes de *Kluyveromyces lactis* selecionados em cultura contínua utilizando soro de queijo ultrafiltrado. Viçosa, UFV. **Imprensa Universitária**, 59p., 2001 (Tese de Mestrado).

CAPITANI, C. D. *et al.,* Milk whey protein recuperation by coacervation with polysaccharide. **Pesquisa agropecuária brasileira**, v. 40, n.11, 2005, p.1123-1128.

CARDI, L. Intumescimento filamentoso no processo de lodos ativados aplicados ao tratamento de soro de queijo: caracterização e uso de floculantes.

CARNEIRO, J. C. S.; MINIM, V. P. R.; SOUZA JR, M. M. de. Sensory profile and acceptability of cultivars of beans (*Phaseolus vulgaris L.*). **Ciência e Tecnologia de Alimentos**, v. 25, n.1, 2005, p.18-24.

CARVALHO, M. P. Soro de leite uma oportunidade desperdiçada. In: **A cadeia produtiva do leite em 40 capítulos**. Juiz de Fora: Embrapa Gado de Leite. 2005.

CASALIS, J. Consideraciones sobre ia utilización de acto suero en la industria de alimentación. **Rev. Espanõla de Lecheria**, v.94, n.221, 1974.

CONDACK, L.; FURTADO, M.M.; MOSQUIM, M.C.A.V.; RODRIGUES, L.H. Utilização do concentrado protéico de soro ultrafiltrado (CPSU) na fabricação de requeijão cremoso. **Rev. lnst. Latic. Cândido Tostes**, v.49, n.289, p.46-54, 1994.

CRISTIANINI, M.; ROIG, S.M. Uso de sólidos de soro de queijo na fabricação de iogurte. **Rev. Instit. Latic. Cândido Tostes**, v.42, n.250, p.41-44, 1987.

CEBALLOS, B.S.O; KONIG, A., LIMA, L.M.M. Comportamento das águas residuais brutas e tratadas de uma industria de laticínios durante um dia de funcionamento. Anais do **XXVII Congresso Internacional de engenharia Sanitária e Ambiental, 2000.**

CHAVES, K. F.; CALLEGARO, E. D.; SILVA, V. R. O. Utilização do soro de leite nas indústrias de laticínios da região de Rio Pomba-MG. In: CONGRESSO NACIONAL DE LATICÍNIOS, 27.,2010, Juiz de Fora. **Anais do Congresso Nacional de Laticínios.** Juiz de Fora: EPAMIG/ILCT, 2010. 1 CD-ROM. **Dairy Science**, v.52, n.6, p.901, 1969.

DALLAS, P. e LAGRANGE, V. **Aplicações de derivados de soro em produtos lácteos. Indústria de Laticínios** v.2 n.13:49-51. 1998.

de β-galactosidase de *Kluyveromyces fragilis*. **Revista de Farmácia e Bioquímica da Universidade de São Paulo**, v. 29, n. 1, p. 25-30, 1993.

OMAR, M.M.; ASHOUR, M.M. **Studies on the whey utilization in cheese making as Cheese**. Mahrunj, v.25, n.8, p.741-748, 1981.

DENDER, A. G. F. **Revisão atualizada de pesquisa – soro de queijo. Seminário proteínas de soro de leite – uso de queijo como ingrediente**. São Paulo. 1997.

FAIN-JR.; LOEWENSTEIN, M.; SPECK, S.J.; BARNHART, H.M.; FRANK, J.F. Cottage cheese whey derivatives as ingredients of coftage cheese creaming mixes. **Journal of Dairy Science**, v.63, n.6, p.905-9l1, 1980.

Enzyme Microbiology and Technology, v.6, p.242–253, 1984.

FERREIRA, C. L. L. F. **Produtos lácteos fermentados: aspectos bioquímicos e tecnológicos.** Viçosa, MG: Ed. UFV, 2001.

FITZSIMONS, S. M.; MULVIHILL, D. M. *et al.,* Denaturation and aggregation processes in thermal gelation of whey proteins resolved by differential scanning calorimetry. **Food Hydrocolloids**, v.11, n.4, p.62-69, 2006.

FRASER, P. D.; BRAMLEY, P. M. The biosynthesis and nutritional uses of carotenoids. **Progress in Lipid Research**, v. 43, p. 228-265, 2006.

FRAZÃO, N. **Estudo do mercado de soro lácteo em Portugal**. Anil, 2001.

FURLAN, S.A.; CARVALHO-JONAS, M.F.; MERKLE, R.; BÉRTOLI, G.B.; JONAS, R. Aplicação do sistema *Microtiter Reader* na seleção de microrganismos produtores de beta-galactosidase. **Arquivos de Biologia e Tecnologia,** v.38, p.1261-1268, 1995.

FURTADO, M. M.; **A arte e a ciência do queijo** – 2º Edição, Editora Globo, São Paulo – SP, 1991.

FURTADO, M.A.M. & WOLFSCHOON-POMBO. Quantificação de soro de queijo adicionado ao leite pasteurizado através da determinação do número de caseína. **Rev. do Inst. de Latic. Candido Tostes**, 42(260):3-11, 1988.

GILLILAND, S.E.; STEWART, C.F. Arnount of yeast and whey protein recovered from cottage cheese whey cultured whit kluveromyces fragilis. **Journal of Dairy Science**, v.63, n.6, p.989-990. 1980

GODINA, A.L. **Proteínas de origem láctea em preparados alimentícios**. Via Láctea, v.25, n.21, 1974.

HIDALGO, J.; CAMPER, E. Solubility and heat stability of whey protein concentrates. **Journal of Dairy Science**, v.60, n.1515, 1977.

HOLMES, D.G. Whey products. New Zeland. **Journal of Dairy Science and Technology**, v.14, n.2, p.208-211,1979.

HOLSINGER, V.H.; POSATI, L.P.; DEVILBISS, E.D. Whey beverages: A review. **Journal of Dairy Science**, v.57, p.849-859, 1974.

HOMEM, G.R. **Avaliação técnico-econômica e análise locacional de unidade processadora de soro de queijo em Minas Gerais**. Viçosa: UFV, 2003.

HUGHES, D. B.; TUDROSZEN, N. J.; MOYE, C. J. The effect of temperature on the kinetics of ethanol production by thermotolerant strain of *Kluyveromyces marxianus*. **Biotechnology Letters.** V. 6, p. 1-6, 1984.

IAL - INSTITUTO ADOLFO LUTZ. **Métodos físico-químicos para análise de alimentos**. 5ª ed. Brasília: IAL, 2008.

JAY, J. M. **Microbiologia de Alimentos**. Porto Alegre: ARTMED. 6. ed, 2005.

JIANG, J. Volatile metabolites produced by *Kluyveromyces lactis* and their changes during fermentation. **Process Biochemistry**, v. 30, n. 7, p. 635-640, 1995.

JULIANO, A.M.M.; PETRUS, J.C.C e TORRANO, A.D.M. **Recuperação por ultrafiltração das proteínas do soro para produção de queijos.** Ver. Inst. Cândido Tostes v.42 n.251:3-6.1987.

KOSIKOWSKI, F.U. Greater utilization of whey powder for human consumption and nutrition. **Journal of Dairy Science**, v.50, n.8, p.l343-1345, 1967.

KOSIKOWSKI, F.V. **Whey utilization and whey products**. Journal of Dairy Science. v. 62, n. 7, p. 1149-1159, 1979.

KUMAR, V. 1988. **Cloning and expression of the Aspergillus niger ß-galactosidase gene in Saccharomyces cerevisiae**. Ph. D. Thesis, University of London.

LAGRANGE, V. e DALLAS, P. **Produtos de soro dos EUA: disponibilidade, recursos tecnológicos, aplicações. Engenharia de Alimentos** v.15:27-29.1997.

LANDRAF, M.G.M.; FRANCO, B.D.G **Microbiologia dos Alimentos**. São Paulo: Ed. Atheneu, 2002.

LOUVEL, M.; BREUNIG, K. D.; FUKUHARA, H. *Kluyveromyces lactis* – areview. **Molecular Microbiology**, v. 25, p. 139-188, 1996.

MACEDO, R. E. F. (1997), Desenvolvimento de bebida láctea fermentada a base de Extrato Hidrossolúvel de Soja e Soro de leite de búfala por cultura mista de *Lactobacillus casei Shirota* e *Bifidobacterium adolescentis*. **Dissertação de Mestrado**, 98 p., Universidade Federal do Paraná, Curitiba, Brasil.

MANN, E.J. Whey utilization. Part 1. **Dairy Industries lnternational**, v.7, n.21, 1976.

MATHUR, B.M., SHAHANI, K.M. Use of total whey constituints for human foods. **Journal of Dairy Science**, 62: 99-105, 1979.

MATOS, A.T. **Tratamento de Resíduos Agroindustriais**. Viçosa: AEAGRI. 2005, 1p. (Curso sobre Tratamento de Resíduos Agroindustriais).

MIRANDA, T.L.S.; SANTOS, R.C.S.; PORTO, L.M. Determinação das melhores condições operacionais do processo de produção da ricota. **B. CEPPA**, Curitiba, v.23 n.1, p.173-182, jan/jun.2005

MOHLER, M.R., HUGUNIN, P.G., EBER, S.K. Whey-bases nonfat milk replaces in light chocolate-flavoured compounds coolings. **Food Technology**, v.35, n.6, p.79-81, 1981.

MORA, C. V. Effect of heting and elevated temperature storage on cheese whey. **Journal of Food Science**, v. 55, n. 4, p. 1177-1179, 1990.

MORR, C.V. Whey protein concentrates: an update. **Food Tecnology**. v.30, n.3 p.18-22, 42, 1976

NELSON, F.E.; BROWN, W. Corroson whey utilization in fruit juice drinks. **Journal of** NETO, R.S.; PASTORE, G.M. Seleção de Microrganismos Produtores de Gamadecalactona. **In:** 4º Simpósio Latino Americano de Ciência de Alimentos, Campinas, SP, 2001.

ORCHARD, R.L. Waster and effluent requirements of the dairy industry. **American Dairy Review**, v.45, n.5, p. 45-57, 1972.

ORDÓÑEZ, J. A.; **Tecnologia de Alimentos: Alimentos de origem animal** – Volume 2, Editora Artmed, Porto Alegre – RS, 2005.

PACHECO, M. T. B.; ANTUNES, A. E. C.; SGARBIERI, V. C. **New technologies and physiological functional properties of milk proteins.** 1 ed. New York: Nova Science Publishers, 2008. 244p.

PACHECO, M. T. B.; DIAS N. F. G.; BALDINI, V. L.; TANIKAWA, C.; GARBIERI, V. C. Propriedades funcionais de hidrolisados obtidos a partir de concentrados protéicos do soro de leite. **Ciência e Tecnologia de Alimentos**, v.25, n.2, p.333-338, 2005.

para melhorar a sedimentabilidade. **Engenharia Ambiental,** v.4, n.2, p.26-37, 2007.

PELEGRINI, D. H. G.; CARRASQUEIRA, R. L. Aproveitamento do soro do leite no enriquecimento nutricional de bebidas. **Brazylian Journal Food Technology,** v.62, n.6, p.1004-11, 2008.

PONSANO, E. H. G. & CASTRO-G´OMEZ, R. J. H. Fermentação do soro de queijo por kluyveromyces fragilis como alternativa para redução de sua capacidade poluente. **Ciência e Tecnologia de Alimentos**, v. 15, n. 1, p. 170-173, jul.-dez. 1995.

PRUDENCIO, E. S.; BENEDET, H. D. Aproveitamento do soro de queijo na obtenção do extrato hidrossolúvel de soja. **Ciência e Tecnologia de Alimentos**, Campinas, v. 19, n. 1, 1999.

REVILLION, Jean p., BRANDELLI, Adriano e AYUB, Marco A. Z. Produção de extratos de leveduras de uso alimentar a partir do soro de queijo: abordagem de elementos técnicos e mercadológicos relevantes. **Ciência e Tecnologia de Alimentos**, v. 20, n. 2, p. 246-249, maio/ago.2002.

RICHARDS, N. S. P.S. Emprego racional do soro láctico. In: **Indústria de laticínios**. p. 67-69. mai/jun 1997.

SARIASLANI, F.S.; ROSAZZA, J.P.N. Biocatalysis in Natural Products Chemistry. SCHAFFRATH, R. & BREUNING, K. D. Genetics and molecular physiology of SEREBRENNIKOV, V. M. Effects of temperature on the biosynthesis of 2,3-butanediol and acetoin under varying conditions of batch culturing of *Bacillus polymyxa* CCM 1465 Appl. Biochem. Microbiol. (1995) **6**, 537-542

SEVERO, L.M.B. Desenvolvimento de uma bebida láctea a base de soro de leite fermentado. **Tese mestrado**. 74p. Universidade Estadual de Londrina. Londrina, 1995. SILVA, K.; BOLINI, H.A. Avaliação sensorial de sorvete formulado com produto de soro ácido de leite bovino. In: **Ciência e Tecnologia de Alimentos**. n.26 p.116-122, jan/mar 2006.

SILVA, M. E. C.; PACHECO, M. T. B.; ANTUNES, A. E. C. Estudo da viabilidade SILVA, M. R. (1999), Elaboração e avaliação de uma bebida láctea fermentada a base de soro de leite fortificada com ferro. **Dissertação de Mestrado**, 121 p., Universidade Estadual de Campinas, Campinas, Brasil.

SILVA, N.; JUNQUEIRA, V. C. A; SILVEIRA, N. F. **Manual de métodos de análise microbiológica de alimentos.** São Paulo: Varela, 1997.

SILVEIRA W. B.; PASSOS, F. J.; MANTOVANI, H. C.; PASSOS, F. M. Ethanol production from cheese whey permeate by *Kluyveromyces marxianus* UFV- 3: A flux of oxido-reductive metabolism as a function of lactose concentration and oxygen level. **Enzyme and Microbial Technology.** V. 46, p. 141-209, 2005.

SILVEIRA, W. B. Produção de etanol em permeado de soro de queijo por *Kluyveromyces lactis* UFV-3. Viçosa, UFV. Imprensa Universitária, 56 p., 2004 (Tese de Mestrado).

SINGLETON, A.D. **The use of whey in dairy products**. Illinois, 1972. SISO, M.I.G. **The Biotechnological utilization of cheese whey: A review**. Bioresource Technology, v.57, p.1-11, 1996.

SOAVE, P.B.; LACERDA, T.H.M. Acompanhamento da vida útil de bebidas lácteas: influência do soro do queijo e culturas contendo organismos probióticos. Anais da **V amostra acadêmica da UNIMEP**, 2007.

SOUZA, J. R. M.; BEZERRA, J. R. M. V.; BEZERRA, A. K. N. A. Utilização de soro de queijo na elaboração de pães. **Revista Ciências Exatas e Naturais**, v. 7, n. 1, 2005.

SUZART, C.A.G.; DIAS, J.C.T. **Desenvolvimento Tecnológico de Aguardente de Soro de Queijo.** Campus Juvino Oliveira: Itabuna, 2007.

TAHARA, S.; MIZUTANI, J. Gama-lactones produced by *Sporobolomyces odorus*. tecnológica da aplicação de coacervado de soro de leite com carboximetil celulose em iogurte probiótico. **Brazylian Journal Food Technology**, v.13, n.1, p.30-37, 2010.

TEIXEIRA, J.A.; DOMINGUES, L.; LIMA, N. **Novas tecnologias para a fermentação alcoólica do soro de queijo.** Universidade do Minho, Braga, 2000.

TORRES, C. C. **Bebidas à base de soro de queijo: caracterização físico-química, microbiológica e sensorial.** Tese mestrado. 117p. Universidade Federal de Viçosa. Viçosa. MG. 1988.

TORRES, C.C.; BRANDAO, S.C.C.; PINHEIRO, AJ.R. Desenvolvimento de bebidas de baixo custo com soro de queijo. **Rev. lnstit. Latic. Cândido Tostes**, v.44, n.261-266, p.71- 84, 1989.

TORTELLI, S. (2002), Desenvolvimento de bebida láctea fermentada utilizando como substratos extrato hidrossolúvel de soja e soro de leite. **Trabalho de Conclusão de Curso**, 78 p., Universidade Regional Integrada, Erechim, Brasil.

TORTELLI, S., Di LUCCIO, M., DARIVA, C., VALDUGA, E. e Oliveira, D. (2002), Otimização do crescimento de uma cultura mista de S. thermophilus e L. delbrueckii subsp. bulgaricus em função da temperatura, pH e agitação. **Anais do Congresso Brasileiro de Ciência e Tecnologia de Alimentos**, Porto Alegre, v.1, CD-ROM.

VANANUVAT, P.; KINSELLA, J.E. Production of yeast protein from crude lactose by *Saccharomyces fragillis*. Batch culture studies. **Journal of Food Science**, v.40, n.2, p.336- 341, 1975

VARGAS, M.A.O.; VARGAS, O.L., LIMA, A. Estudo para substituição da água de cocção do arroz por soro de queijo de leite de vaca. **Rev. Instit. Latic. Cândido Tostes,** v.38, n.227, p.4l-46, 1983.

VOOBERGEN, M.; ZWANENBERG, A. Whey-ing up the future. **Dairy Industries International**, v.67, n.1, p.25-28, 2002.

WALKER, G. M. **Yeasts physiology and biotechnology.** Ed. Jonh Wiley & Sons Ltd. New York. 1998.

yeast *Kluyveromyces lactis* – a review. **Fungal Genetics and Biology**, v. 30, p. ZADOW, J.G. **Utilisation of milk components: whey**. In: ROBINSON, R. K. **Modern Dairy Technology** vol. 2. Advances in Milk Products. 1997.

ZUÑIGA, A.D.G.; COMIBRA, J.S. R. **Propriedades funcionais e nutricionais das proteínas do soro de leite**. Revista do Instituto de Laticínios "Cândido Tostes", v. 57, no 325, p. 35-46. mar/abr. 2002.