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Chapter

Introductory Chapter: Dairy By-Products - Why Should We Care?

Isabel Gigli and Mario Calafat

1. Introduction

This book focuses on low investment alternative use of dairy by-products. Whey has application in both the pharmacology and nutritional industry. However, three main problems affront cheese makers when they try to process whey: the short half-life, the cost of refrigerating, and transportation cost. All these make the use of whey economically difficult for small and medium manufacturers. Therefore, in most cases, whey ends up as agro-industrial waste. This represents a loss of valuable opportunities and also, as explained below, represents a high environmental impact. In the different chapters, the authors offer alternative biotechnology processes (**Figure 1**). The ultimate goal of the book is to break the paradigm of considering milk by-product as a waste. This introductory chapter provides the global context in which the book was conceived: starts with a historical and current perspective of the consumption of dairy products, continues with the composition of the by-products, followed by our experience of using whey as culture media to produce mineral organic supplement and then isotonic lactose-free beverage, and closes with a general conclusion.

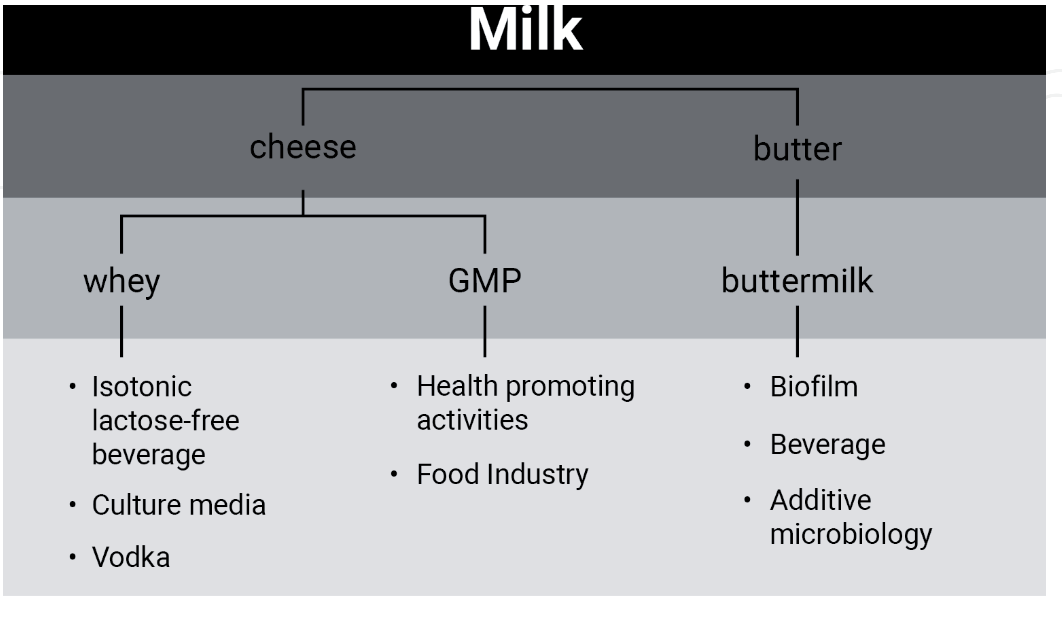

Figure 1.
Alternative use of whey and buttermilk discussed in this book.

2. Dairy products consumption: past and present

Cow milk has been part of the human diet for 11,000 years. In the 1970s, archeologist Peter Bogucki while excavating a Stone Age site in Poland found a leaky clay pot. It was not until 2011 when molecular studies performed by Mélanie Roffet-Salque identified milk fat residues [1]. The researcher, a UK geochemistry, concluded that the container constituted evidence that prehistoric farmers used the ceramic as sieves to separate milk solids from whey. This pot is the oldest known evidence of cheese making in the world. Cheese has been a nutritional contribution in the diet of many cultures. Nowadays, 6 billion people around the world consume milk and milk products [2]. In South America alone, milk production reached 61.8 million tons in 2017 [3]. In this region, the largest producers are Brazil, Colombia, and Peru. In Brazil, fluid milk market predominates over manufacturing dairy products. While in Argentina, Mexico, Chile, and Colombia, the cheese and butter markets are more important than fluid milk [4] as it is shown in **Table 1**.

The need to produce safe and nutritious food without environmental impact is a global challenge. Technology has contributed to improve agricultural and livestock productivity, but at the same time, the increase in production has had a negative impact, such as environmental and water pollution, deforestation, and biodiversity loss. The Food and Agriculture Organization of the United Nations estimates that by 2050, food production should increase by 70% over current production [5]. This information together with the information that currently a third of the global food is lost or waste [5] highlights the importance of rethinking food production. The term **food loss** refers to losses that occur during the supply chain between the producer and the market (e.g., during sowing, harvesting, or transporting). **Food waste** refers to the nonuse or nonfood use that can be given to raw material safe and nutritious suitable to be converted into food. The last one is the case of dairy by-products, especially in developing countries where the energy cost for technological processes such as drying or protein purification makes it economically difficult. While we are being inefficient in food production, around 870 million people do not have access to sufficient dietary energy and as a consequence suffer chronic malnutrition. Therefore, nothing should justify the voluntary loss of raw materials that could be transformed into food. The nonuse of by-products that could be transformed into food represents a waste of food and also a waste of the resources used to produce them. This inefficiency also harms environmental sustainability. Lactose is a strong pollutant due to its high oxygen demand. It is important to find alternative uses of milk by-product to avoid or at least reduce food waste.

Country	Annual milk production ($\times 10^6$)	Milk percentage (%) destined to cheese
Argentina	11.338	41
Brazil	33.400	38
Colombia	6.772	35*
Uruguay	2.100	35

Table 1.
Annual milk and cheese production in South America (2012–2013) [4].

3. Whey

Whey is the remaining liquid that is produced after milk has been curdled and strained during the manufacturing of hard and semihard cheese. Depending on the process of casein precipitation, whey can be acid or sweet. Acid whey is formed when lactic acid bacteria are added to milk, and sweet whey is formed when the coagulation process is started by adding chymosin. Whey contains 90% of milk water and 50% of milk nutrients (**Table 2**). The major whey proteins are lactoglobulin, lactalbumin, serum albumin, immunoglobulins, and glycomacropeptide, while minor whey proteins include lactoperoxidase and lactoferrin among other proteins (**Figure 2**). These globular proteins are water soluble and contain all nine essential amino acids. **Tables 2** and **3** show the composition and the vitamins present in whey, respectively. As it can see, whey is nutritional and, in spite of that, it is rarely used as such. One problem of using whey as a food is the high concentration of lactose that makes it difficult to digest especially for people intolerant to this carbohydrate (lactose intolerance). For lack of alternative uses, what happens is that it ends up being discarded as an effluent.

The amount of discarded whey is difficult to quantify for obvious reason. The Food and Agriculture Organization (FAO) estimated that 40×10^6 l/day of whey are produced in South America, and the largest amount is discarded. In Argentina, the dairy industry produces around $11,338 \times 10^6$ l/year. Approximately, 41% is used for the production of cheese. This volume is equivalent to producing 4.015×10^6 l/year of whey. Fifty-five percent of that volume is used in part to feed animals and most of it is discarded as waste [4].

Whey has a negative environmental impact for both soils (due to mineral concentration) and water (due to lactose concentration) Although this is well known, what is observed in most cheese factories is that whey is discarded, without treatment or with a minimum treatment that fails to reduce the chemical oxygen demand (COD) to acceptable values (marcos murcia, personal communication). As a way to contribute to the search of solutions to this problem, our group seeks simple and economical alternatives to implement the use of whey. Below, two alternatives are discussed. First, we discuss the use of whey as a culture medium for yeast enriched in specific minerals and, second, a beverage elaboration carried out by a group of students from an agricultural school under our direction. This last experience, we believe, is important to visualize the problem and promote the local production.

3.1 Whey as a culture media to obtain selenium-enriched yeast

The concentration of minerals present in the soil varies according to the geographical area. When a mineral is deficient in soils, livestock needs to be

Composition	%
Fat	0.7
Total protein	0.9
Lactose	4.5
Total solid	6.7
No fat solid	6.1

Table 2.
Whey composition [6].

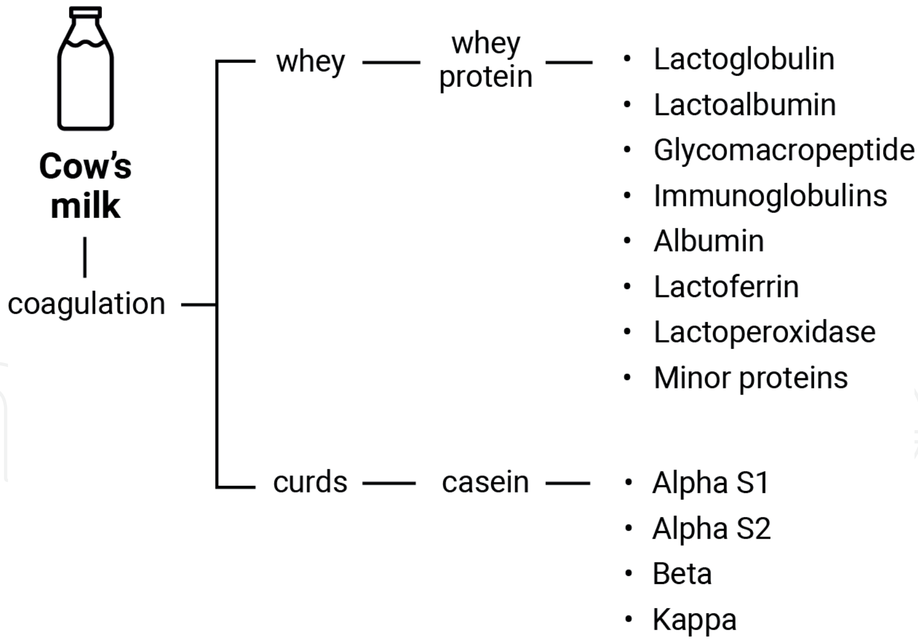

Figure 2.
Whey and curd protein composition.

Amino acid	%
Thiamine	0.3
Folic acid	0.7
Niacin	1.2
Riboflavin	0.2
Choline	108.0
Pantothenic acid	4.0

Table 3.
Vitamin concentration in whey [7].

supplemented. In the semiarid region, for example, a low concentration of selenium is observed [8]. Selenium is a cofactor of different enzymes such as glutathione peroxidase, which is involved in the antioxidant systems [9]. Also, selenium plays an important role in thyroid hormone synthesis [10]. Although the animal requirement for this mineral is low (300 μg/ dry matter) [11], selenium deficiency affects health and productivity. In cows, immunological suppression, placental retention, and decreased milk production have been reported associated with selenium deficient [12, 13]. In calves, diets deficient in selenium can cause a lethal condition called white muscle [14]. In order to find an alternative use to whey and at the same time offer a solution to the geographical areas that have selenium deficiency, we developed an economical culture using whey for the growth of yeast expressing lactase (Kluyveromyces DSM 11954). In this way, lactose is used to obtain selenium-enriched biomass. The whey-based culture medium (whey, $(NH_4)_2SO_4$ and K_2PO_4) was supplemented with 20 μg/ml of Na_2SeO_3. At the end of the process, a total of 550 g wet cell weight (WCW) was equivalent to 85 mg/kg yeast selenium concentration. We then studied the effect of selenium-enriched yeast on calves. Six calves received 7 g of K. *marxianus* daily for 10 days (0.60 mg of selenium/animal/day). The supplement was offered individually to the animals, mixed in a small amount of grains. The animals showed no signs of rejection of the supplement. The level of selenium in the blood was measured at Day 0 (before supplementation) and at Day 10 of treatment. The animals showed a significant increase in selenium blood ($p < 0.005$) (**Figure 3**) [6]. The use of whey as a culture medium is an inexpensive way to produce organic mineral supplements and at the same time reduces the environmental impact caused by the concentration of lactose in wasted milk by-product.

3.2 Whey as an isotonic, lactose-free beverage

Water footprint is the amount of direct and indirect water used to produce a product. It is estimated that a glass of milk (200 ml) requires 250 l of water (1 water l/1000 milk l) [15]. Taking into account that whey contains 90% milk water and is discarded without use, it is surprising that no further efforts are made to avoid the waste of such a volume of water. In addition to water, whey—as mentioned above—is a source of all essential amino acids. In Chapter 2 of this book, a fermented beverage process from whey is described. Here, whey is discussed as an isotonic drink. Whey has been promoted to be used as a sports drink as it contains all minerals to replace the electrolyte losses in sweat and carbohydrate [16, 17]. **Table 4** shows whey and commercial sport drinks mineral concentration. Isotonic drinks help prevent blood sodium dilution, a dangerous situation that occurs when athletes, especially in long distance events, drink water in excess [21]. Athletes need to replace water and minerals during and after an endurance event. Mineral losses by sweat include sodium, potassium, magnesium, chloride, and calcium. All of these minerals play important biochemical and physiological roles in the body. Another nutritional advantage of whey protein is that it has a high level of leucine (11.8% of total protein), which is important in sports supplementation when the objectives are muscle repair and growth. For example, Hamarsland et al. [22] reported higher blood leucine concentration and higher muscle protein rates after exercise when athletes consumed native whey, compared to milk or WPC-80. Reitelseder et al. [23] quantified labeled L-[1-13C] leucine in muscle and compared two different treatments: casein and whey ingestion. The authors observed no difference in protein muscle synthesis. These results are important because they valorize the use of whey compared to more costly technological processes. The point that must be emphasized is that the promotion of whey as a beverage will help reduce environmental pollution and develop a new commercial option to use a by-product that, otherwise, is considered a waste.

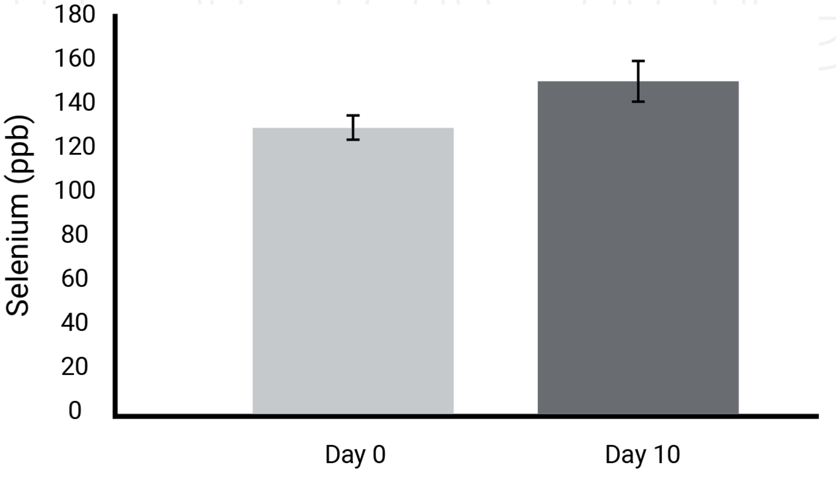

Figure 3.
Selenium blood levels (ppb) in calves before (Day 0) and the day after selenium-enriched yeast supplementation (Day 10).

Mineral	Sweet whey (mg/100 ml) [18]	Acid whey (mg/100 ml) [18]	Gatorade (mg/100 ml) [19]	Powerade (mg/100 ml) [20]
Calcium	92.8	36.5	—	—
Phosphorus	58	43	—	—
Magnesium	9	6.5	—	—
Potassium	58	43	45.8	104.2
Sodium	39.5	45.5	12.5	24.2

Concentration in whey can vary according to whey processing.

Table 4.
Mineral concentration in sweet whey, acid whey, and commercial sport drink Gatorade and Powerade.

Keeping the idea of finding alternative products for whey, the authors of this chapter collaborated with students of Agriculture School (Escuela Agrotécnica Victorica, La Pampa, Argentina) to produce a lactose-free beverage based on whey. The students developed the product as part of their laboratory assignment for the Nutrition course. **Figure 4** shows the production flow, and **Figure 5** shows the final product. In this way, the students visualized and understood that with a simple process, what is considered a waste can be transformed into food.

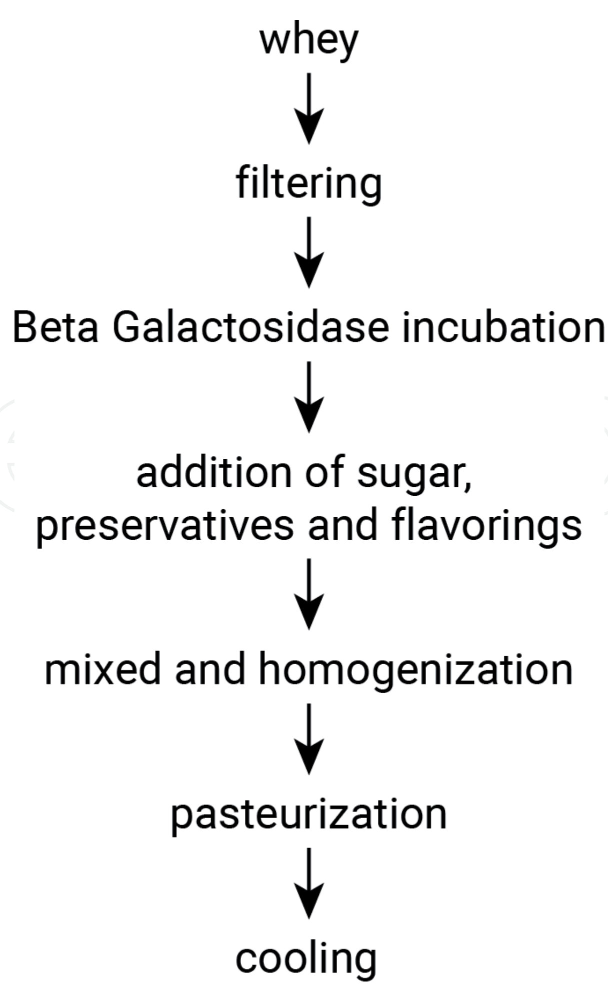

Figure 4.
Lactose-free whey beverage production flow.

Figure 5.
Lactose-free whey beverage produced by students of Agriculture School Victoria (Escuela Agrotécnica Victorica, La Pampa, Argentina).

4. Conclusion

Whey is still considered a by-product with no economical value despite its biological properties and despite all the alternative uses that have been proposed. The uses of whey as a culture medium or as a beverage, as discussed here, are examples of how simple processes can contribute to the development of new products and at the same time to reduce environmental impact. We are intensifying production systems and genetically improving livestock to produce more milk; meanwhile, we are discarding 50% of the nutrients in milk as whey. This should be considered also as part of lack of animal welfare. We do not need to produce super cows, with all the metabolic stress that it causes to the animal; we need to rethink the systems of food elaboration.

It is important to discuss the way we are producing food and the biological value of the food we want to consume. Environmental and production policies that favor the use of by-products are required. We need to break the paradigm of considering milk products as waste and develop new strategies for use.

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