Graduate Student Literature Review: History, technologies of production, and characteristics of ricotta cheese*

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ABSTRACT

This review focused on the historical, technological, and analytical characteristics of ricotta cheese available in the literature. Ricotta cheese is a typical dairy product that originated from Italy, used in the preparation of several traditional dishes, both sweet and salted. The available studies pertaining to ricotta cheese revealed a considerable biodiversity in the production with a large number of varieties produced, whose production varies according to the local uses and customs. The review shows the main chemical and microbial characteristics of the product and also the several parameters that affect the mechanism of the production process and the final characteristics of the product, including the raw materials, the processing methods, the season, the animals’ diet, the animals’ species, and breeds. Ricotta production can be artisanal or industrial, with differences in the making process. New trends in ricotta cheese production have been developed, with particular attention to the functional effect on human health and the novel technologies applied to extend the shelf-life of the products. Currently, it is not easy to find these new developments in the market, probably related to the cost of production, which is not always bearable by the farms. However, despite the large classification reported and the great interest by the cheese industry, just a few numbers of studies were found for artisanal ricotta productions, which still need to be characterized and studied.

Key words: ricotta cheese, ricotta production, analytical characteristics, new trends

INTRODUCTION

Ricotta cheese is a typical dairy product, mostly known as unripened acid-heat coagulated-soft whey cheese that originated from Italy, especially in the south, but also popular in the Mediterranean area (Del Nobile et al., 2009) and internationally (Paskaš et al., 2019). The origin of the name derives from the Latin word re-cocta, literally “recooked” or “cooked twice,” which refers to the technology used for the production of this product. According to Italian legislation (I.R.D., 1925), ricotta is not properly a cheese but a by-product of cheesemaking, and is produced from whey and not from milk (Scatassa et al., 2018); moreover, in agreement to the Codex Alimentarius (2011) and the UNI standard 10978:2013 (UNI, 2013), it is also classified as whey cheese within the class of dairy products.

Ricotta cheese is classified as a soft dairy product (Modler and Emmons, 2001), with a high humidity content ranging between 65 and 75%. Traditionally, the primary ingredient used for the manufacture of ricotta cheese is whey collected during the mozzarella cheese production (Farkye 2004) but also from other cheeses, such as hard sheep milk cheese or stretched cow milk cheese (Licitra et al., 1998). Therefore, it can be made mainly from sheep or goat whey, or a mixture of both, but also from cow and buffalo whey (Mucchetti et al., 2002; Mucchetti and Neviani, 2006). In particular, it has typically been prepared by heating whey and acidifying the hot liquid to coagulate whey proteins (Modler and Emmons, 2001; Pizzillo et al., 2005). The agglomerated curd mass that floats to the surface is collected and transferred into perforated baskets to drain the scotta whey (Modler and Emmons, 2001).

Fresh ricotta has a compact mass and granular and creamy texture, with a slightly perceptible flavor and uniform yellowish-white color (Pintado et al., 2001). It is very mild, and due to these properties, it can be used as is or as an ingredient in many dishes such as cheesecake, pasta, pizza, and sandwiches (Del Nobile et al., 2009).

Production of ricotta cheese has been considered to be one of the economical ways to use whey and create
an additional source of income (Shukla and Manhtl, 1986) for all cheesemakers, especially at the artisanal level. The whey derived from cheesemaking can be considered one of the main by-products of the dairy industry, and more than 50% produced is used for animal feeding, as biofertilizer, or discharged without any treatments, representing a further cost for dairy plants (Vincenzi et al., 2014; Cassano et al., 2019; Kotoulas et al., 2019; Ostertag et al., 2021). Thus, the production of ricotta can be considered as a system of adding value to a cheesemaking residual waste, largely employed in Italy both at the artisanal and industrial production level (Sattin et al., 2016). In Italy, around 15% of the whey obtained annually from cheesemaking is used to produce ricotta (Maragkoudakis et al., 2016).

The demand for ricotta cheese in the market has increased gradually in the last few years. This phenomenon is mainly related to consumers’ preferences for more natural and healthy foods with high nutritional value (Puccio et al., 2022). To export ricotta beyond the local market to the international level, a lot of research has been developed for novel preservation techniques, including the use of nonthermal treatments and the use of additional ingredients (Ricciardi et al., 2019). Indeed, the main problem particularly focused on in the literature was represented by the shelf-life, which was limited to 2 to 3 d even under refrigeration, in the fresh product (Hough et al., 1999). Ricotta production can be distinguished into artisanal and industrial production. Although the main ingredient (whey) and the principles of production are the same, studies revealed the difference in shelf-life evaluation between the 2 types of production. Different reviews are available for whey cheeses, by classifying the different varieties, ingredients used, and origin; however, no reviews have focused only on ricotta cheese.

The present article aims to give an overview of the classification of the different kinds of ricotta produced, the raw materials used, the parameters that affect the final quality, the methods of production applied (artisanal vs. industrial), and the chemical, physical, and microbial characteristics as well as new trends in ricotta cheese production technologies, to improve the quality and extend the shelf-life.

No human or animal subjects were used, so this analysis did not require approval by an Institutional Animal Care and Use Committee or Institutional Review Board.

HISTORICAL BACKGROUND OF RICOTTA CHEESE

The production of ricotta cheese seems to be diffused on the Italian peninsula during the second-millennium BC, as deduced from the abundant presence of historical tools used in the cheesemaking found in the archeological record (Kindstedt, 2017), and it is probably the oldest and the best known in the world (Pintado et al., 2001).

The history of ricotta cheese is widely illustrated by various authors and historians, who over the centuries have mentioned its production, goodness, and delicacy. Greeks and Romans already made ricotta, as Columella described the various phases of its production in the first century A.D. in his book De Re Rustica. The work “Vita di pastori nella Campagna Romana” by Trinchieri (1953) described the production of the Ricotta Romana cheese. Achille Bruni, professor of the Royal University of Naples, in his monograph “Del latte e dei suoi derivati,” published in 1859 in the New Agricultural Encyclopedia, briefly described how Ricotta di Bufala was produced at that time.

In the work “Giornale di viaggio fatto in Sicilia particolarmente nella contea di Modica” by Abbot Paolo Balsamo, dating to 1808, the production of ricotta and cheeses in the Ragusa area is highlighted, also enhancing the quality of pastures and livestock. The author tells of different quantities of ricotta produced, depending on the territories and producers, and the number of animals (e.g., 15 t produced in a single farm in Ragusa, 848 t produced in the entire region of S.S. Qusquina). Balsamo also tells of the custom of producing butter from ricotta that is close to going sour, and defines these products, including ricotta, as among the best in Sicily, an expression of local territories and customs.

CLASSIFICATION OF THE DIFFERENT RICOTTA CHEESES

A large number of ricotta cheese varieties are produced in different areas. According to Muchetti et al. (2002), ricotta cheese can be subdivided into 3 categories, based on the basic production technology, shelf-life, and manufacture type:

1. Ricotta cheese produced by medium-large industrial plants with a long-time shelf-life (20–40 d);
2. Ricotta cheese produced by small-medium industrial plants with a medium-time shelf-life (7 d);
3. Ricotta cheese produced in the mountain pasture, agro-pastoral, or small industrial plants, with a short shelf-life (1–2 d).

These 3 categories, in turn, can be divided according to the animal species from which the whey is derived (bovine, ovine, buffalo, and goat; Muchetti et al., 2002).

A different classification was made in the United States according to the moisture and fat content, by
specifying 3 types of ricotta cheese in which the main ingredient was milk, in particular: whole milk ricotta, part-skim ricotta, and ricotta, or ricottone (Farkye, 2017).

Also, Hough et al. (1999), Pizzillo et al. (2005), and Araque et al. (2018) reported milk as the main ingredient in ricotta cheese production. As stated above, according to the Codex Alimentarius (2011) and the UNI 10978:2013, ricotta cheese is classified within the whey cheeses, in which the main ingredient is whey, not milk. This generate an important issue and a general confusion, revealing a lack of accurate information in the ricotta manufacture reported in some studies in the literature.

Mucchetti et al. (2002) reported that more than 25 varieties of traditional ricotta have been classified, differing in raw material origin, structure, texture, taste, aroma, intended use, production and preservation technology. Several studies have been developed which are focused on the various types of ricotta produced in Italy. The main differences reported in the literature include the production types (i.e., fresh, dry salted or baked), the whey used (i.e., cow, sheep, goat, buffalo), the production technologies (i.e., artisanal or industrial), and the manufacturing area (Table 1).

From Table 1 it is possible to highlight the presence of products unique for their kind. Particular is the Seiras del Fèn, an aged ricotta produced in Piedmont using a mix of sheep, goat, and cow whey and characterized by the wrapping in hay for aging (Zeppa et al., 2005).

Another specific product is represented by Ricotta Forte, a typical production of the Puglia region of ancient origin, produced from sheep, cow, or goat whey proteins as classic ricotta, but characterized by an intense natural fermentation process. This product was described as a soft, strong, and spicy tasting cheese that is the result of a unique manufacturing technology.

### Table 1. Ricotta cheeses produced in Italy reported in the literature

<table>
<thead>
<tr>
<th>Name</th>
<th>Ricotta type</th>
<th>Whey type</th>
<th>Country</th>
<th>Classification</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricotta Toscanella</td>
<td>Salted</td>
<td>Sheep</td>
<td>Italy (Sardinia)</td>
<td>TFP</td>
<td>Scarano et al., 2019</td>
</tr>
<tr>
<td>Ricotta Testa di Morto</td>
<td>Salted</td>
<td>Sheep</td>
<td>Italy (Sardinia)</td>
<td>TFP</td>
<td>Scarano et al., 2019</td>
</tr>
<tr>
<td>Ricotta Molinella</td>
<td>Salted</td>
<td>Sheep</td>
<td>Italy (Sardinia)</td>
<td>TFP</td>
<td>Scarano et al., 2019</td>
</tr>
<tr>
<td>Ricotta Mustia</td>
<td>Salted and smoked</td>
<td>Sheep</td>
<td>Italy (Sardinia)</td>
<td>TFP</td>
<td>Scarano et al., 2019</td>
</tr>
<tr>
<td>Ricotta Gentile</td>
<td>Fresh</td>
<td>Sheep</td>
<td>Italy (Sardinia)</td>
<td>TFP</td>
<td>Pala et al., 2016</td>
</tr>
<tr>
<td>Ricotta Pistoiise</td>
<td>Fresh</td>
<td>Sheep</td>
<td>Italy (Tuscany)</td>
<td>TFP</td>
<td>Pianaccioli et al., 2007;</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Acciaioli et al., 2009</td>
</tr>
<tr>
<td>Ricotta Romana</td>
<td>Fresh</td>
<td>Sheep</td>
<td>Italy (Lazio)</td>
<td>PDO</td>
<td>Filippetti et al., 2007</td>
</tr>
<tr>
<td>Ricotta di Bufala Campana</td>
<td>Fresh</td>
<td>Buffalo</td>
<td>Italy (Campania; Lazio; Puglia; Molise)</td>
<td>PDO</td>
<td>Tripaldi et al., 2020; Miele et al., 2021</td>
</tr>
<tr>
<td>Ricotta di Pecora</td>
<td>Fresh</td>
<td>Sheep</td>
<td>Italy (Sicily)</td>
<td>TFP</td>
<td>Mancuso et al., 2014;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Scatassa et al., 2016</td>
</tr>
<tr>
<td>Ricotta Iblea</td>
<td>Fresh</td>
<td>Cow</td>
<td>Italy (Sicily)</td>
<td>TFP</td>
<td>Scatassa and Mancuso, 2012</td>
</tr>
<tr>
<td>Ricotta di Vacca</td>
<td>Fresh</td>
<td>Cow</td>
<td>Italy (Sicily)</td>
<td>TFP</td>
<td>Scatassa and Mancuso, 2012</td>
</tr>
<tr>
<td>Ricotta di Capra</td>
<td>Fresh</td>
<td>Goat</td>
<td>Italy (Sicily)</td>
<td>—</td>
<td>Scatassa and Mancuso, 2012</td>
</tr>
<tr>
<td>Ricotta Informata</td>
<td>Baked</td>
<td>Cow/sheep/goat or mixed</td>
<td>Italy (Sicily)</td>
<td>TFP</td>
<td>Campo and Licitra, 2006; Scatassa and Mancuso, 2012</td>
</tr>
<tr>
<td>Ricotta Mistia</td>
<td>Fresh</td>
<td>Mixed</td>
<td>Italy (Sicily)</td>
<td>TFP</td>
<td>Scatassa and Mancuso, 2012</td>
</tr>
<tr>
<td>Ricotta Salata</td>
<td>Salted</td>
<td>Sheep</td>
<td>Italy (Sicily)</td>
<td>TFP</td>
<td>Campo and Licitra, 2006; Scatassa and Mancuso, 2012</td>
</tr>
<tr>
<td>Ricotta allo zafferano</td>
<td>Fresh</td>
<td>Sheep</td>
<td>Italy (Sicily)</td>
<td>—</td>
<td>Gaglio et al., 2019</td>
</tr>
<tr>
<td>Ricotta Forte</td>
<td>Fermented</td>
<td>Sheep</td>
<td>Italy (Puglia; Basilicata)</td>
<td>TFP</td>
<td>Baruzzi et al., 2000; Cappello et al., 2003; Mascaro et al., 2010; Rea et al., 2010; Faccia et al., 2018; Vajallo, 2015</td>
</tr>
<tr>
<td>Ricotta Marzotica</td>
<td>Salted</td>
<td>Sheep</td>
<td>Italy (Puglia)</td>
<td>TFP</td>
<td>Pizzillo et al., 2004</td>
</tr>
<tr>
<td>Ricotta Fresca</td>
<td>Fresh</td>
<td>Sheep/goat</td>
<td>Italy (Basilicata)</td>
<td>TFP</td>
<td>Zeppa et al., 2005</td>
</tr>
<tr>
<td>Saras del Fèn</td>
<td>Aged</td>
<td>Cow, sheep, and goat</td>
<td>Italy (Piemonte)</td>
<td>TFP</td>
<td>Faccia et al., 2019</td>
</tr>
<tr>
<td>Sap Ricotta</td>
<td>Fresh</td>
<td>Sheep/goat</td>
<td>Italy (Puglia)</td>
<td>TFP</td>
<td></td>
</tr>
</tbody>
</table>

1TPF = traditional agri-food product; PDO = Protected Designation of Origin.
that requires a considerable amount of handling and natural ripening for 1 yr (Baruzzi et al., 2000; Rea et al., 2010; Mascaro et al., 2010; Faccia et al., 2018). Also in Sicily, a particular and not well known production is Saffron Ricotta, produced from the Piacentinu Ennese PDO cheese production, containing residual saffron spice, with a particular flavor derived from this spice (Gaglio et al., 2019). Also interesting is the ricotta production that uses fig latex (Ficus carica) as an agglomerant in the manufacture of the Sicilian ricotta infornata (baked ricotta) and the Apulian milk sap ricotta (Campo and Licitra, 2006; Faccia et al., 2019).

In the Sicilian ricotta infornata production process fig latex from young twig fig, previously engraved to facilitate the leak of the latex, was dissolved in a water solution and added in the whey and milk mixture to speed up the surfacing of the product. After 2 d, the ricotta cheese is salted, wrapped in cotton fabrics, and baked in a ceramic pan at 80 to 100°C, until the traditional stone oven cools down (for about 24 h). This operation is repeated 4 to 5 times, or when the consistency of the product reaches the ideal level, traditional semi-hard or hard (Campo and Licitra, 2006; Mucchetti and Neviani, 2006).

Electric ovens are also used to produce baked ricotta cheese with some differences in the preparation. Indeed, after 2 d of its production, the ricotta is salted and placed in terracotta containers of variable diameter, depending on the starting quantity of ricotta, without any wrapping with cotton fabrics. Moreover, the oven temperatures which vary from 150 to 300°C, are constant with residence times lower than those of traditional ovens (Campo and Licitra, 2006).

For the production of the traditional milk sap ricotta, caprifig latex (Ficus carica var. sylvestris) is used in the artisanal making process. During production, the caprifig bunch, previously cut to release the latex, is used for stirring. The operation proceeds gradually until the formation of the first flakes on the surface (Faccia et al., 2019).

Many of the traditional ricottas produced in Italy, on a proposal of the Italian Department for Agriculture, are included in the national list of the traditional agri-food products (TFP), which are characterized by manufacturing methods that are consolidated in a specific area for at least 25 yr according to unchanging and constant local use (Uzun et al., 2020). Moreover, among the different types of Italian ricotta cheese, 2 of them are recognized as Protected Designation of Origin (PDO) products, respectively, Ricotta Romana cheese, produced only with sheep whey, or whey added from sheep milk or cream, and Ricotta di Bufala Campana cheese, produced only with buffalo whey, or whey added from buffalo milk or cream (Miele et al., 2021). Thus, products carrying the PDO label conform to the specifications outlined by the European Commission.

The literature shows a considerable biodiversity in ricotta cheese production with a large number of varieties produced in different Italian regions, especially in the artisanal manufacture, whose production varies according to local uses and customs (Table 1). As reported by many studies focused on the main chemical-physical, microbiological, sensory, and texture characteristics, use of different ingredients as coadjuvants in the making process (acidulant, spices, and so on), and implementation of the production process, ricotta is

Table 3. Worldwide ricotta cheese production reported in the literature

<table>
<thead>
<tr>
<th>Ricotta type</th>
<th>Whey type</th>
<th>Country</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh</td>
<td>Cow</td>
<td>Brazil</td>
<td>Guatemim et al., 2016; Andrade et al., 2020</td>
</tr>
<tr>
<td>Fresh</td>
<td>N-S¹</td>
<td>Lithuania</td>
<td>Slapauskaite et al., 2004</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow; sheep</td>
<td>Serbia</td>
<td>Paskaš et al., 2019</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow</td>
<td>Argentina</td>
<td>Hough et al., 1999; Araque et al., 2017</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow; buffalo</td>
<td>Egypt</td>
<td>Gomaa et al., 2015</td>
</tr>
<tr>
<td>Fresh</td>
<td>N-S</td>
<td>Tunisia</td>
<td>Kamel et al., 2013</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow</td>
<td>Russia</td>
<td>Kritchenkov et al., 2020</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow</td>
<td>Portugal</td>
<td>Martins et al., 2010</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow; buffalo</td>
<td>India</td>
<td>Sameer et al., 2020</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow</td>
<td>Belgium</td>
<td>Besbes et al., 2002</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow</td>
<td>Venezuela</td>
<td>Monsalve and González, 2005</td>
</tr>
<tr>
<td>Fresh</td>
<td>N-S</td>
<td>Taiwan</td>
<td>Wu and Lin, 2018</td>
</tr>
<tr>
<td>Fresh</td>
<td>N-S</td>
<td>Chile</td>
<td>Hawkins et al., 2009</td>
</tr>
<tr>
<td>Fresh</td>
<td>Buffalo</td>
<td>Pakistan</td>
<td>Rashid et al., 2017</td>
</tr>
<tr>
<td>Fresh</td>
<td>N-S</td>
<td>Romania</td>
<td>Jurca Paven et al., 2018</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow</td>
<td>United Kingdom</td>
<td>Davies et al., 1997</td>
</tr>
<tr>
<td>Fresh</td>
<td>Cow</td>
<td>United States</td>
<td>Farkye, 2017</td>
</tr>
</tbody>
</table>

¹N-S: not specified in the study.
also produced in other countries and consumed as a part of many diets (Table 3).

RICOTTA CHEESE MANUFACTURE

Traditionally ricotta cheese is made with a primary ingredient represented by the whey derived from the cheese manufacture. The production technology uses the principle of agglomeration and precipitation of the whey protein favored by acidification, with pH values ranging between 6 and 5.8 and heating temperature ranging between 80 and 90°C, resulting in the final product after 10–30 min depending on the type of heating.

In ricotta manufacture, acidulants (i.e., lactic or citric acid) between 1.5 and 2.5% may be added to promote the whey protein agglomeration. Moreover, in some cases, to increase the final yield, during the production whey could be enriched with whole milk or cream (5–15%) and salt (0.5–1.5%; Mancuso et al., 2014). Afterward the whey gel formed is collected in molds to drain the exhausted whey (scotta) and cooled.

The mechanism of surfacing of the whey protein gel is possible because when the fat globules are entrapped into the protein network, the density of the gel becomes lower than that of scotta whey.

The high temperature maintained by ricotta flakes at the surface for some minutes makes the curd network more firm and cohesive, facilitating the separation. The size of the protein aggregation is important for the final structure of the product and to facilitate the scotta drain from ricotta (Mucchetti et al., 2017).

Important aspects must be considered in the mechanism of production of ricotta cheese, including the rheological proprieties, characteristics of the whey, acidification, heat treatments, and the addition of ingredients of enrichment.

Kinetic Process

Ricotta cheese production is the result of an acid/thermal coagulation model. The subtle balance between temperatures, acidity, and salinity of the whey, more or less fortified, during the entire production process, is essential to optimize the yield in ricotta.

The processes that determine the acid/thermal coagulation concern the denaturation of proteins, mainly the whey proteins, due to the thermal effect, and their destabilization due to the acidity and salinity of the medium (Farkye, 2004) followed by the flocculation and aggregation processes. It has been shown that the denaturation and aggregation processes are distinct from each other and depend on the pH, concentration, and ionic strength of the medium (Corredig and Dalgleish, 1996; Dalgleish et al., 1997; Anema, 2001).

From a chemical-structural point of view, the ricotta cheese matrix shows a gel-like structure made of whey proteins, principally α-LA and β-LG, resulting in the formation of bonds that generate an interconnected molecular network that entraps fat globules and moisture fraction, providing elasticity and rigidity to the system (Stading and Hermansson, 1991). Covalent bonds commonly take place via disulfide bridges between whey protein and also between β-LG and casein in this kind of product (Krishnankutti Nair et al., 2013).

Gelation of whey proteins is the result of an aggregation process, induced by the alteration of the conditions, in particular an increase in temperature (Verheul et al., 1998).

Due to the heating, whey proteins partly unfold and, in this denaturation step, nonpolar groups are exposed and in the case of β-LG and BSA-free sulfhydryl groups become reactive (Matsudomi et al., 1991). Moreover, changes in the pH solution, salt type, salt concentration, or heating conditions alter the aggregation and gelling properties of whey proteins (Mulvihill et al., 1990; Renard and Lefebvre, 1992).

An important parameter in developing the protein aggregation and subsequently of the gel structure protein is represented by the ionic strength of the whey. The presence of divalent cations, indeed, such as calcium and magnesium, are crucial to favor the formation of large aggregates by partly shielding the negative charge of whey proteins and bridging between the protein, lowering the electrostatic repulsion (Salvatore et al., 2014). The gel formation derives from the hydrophobic attraction over electrostatic repulsion. The strength of each type of interaction is directed by the residual charge on the proteins, influenced by pH, ionic strength, and Ca binding, and the temperature of the product (Lucey et al., 2003). However, no study have treated these aspects in the mechanism of agglomeration during ricotta cheese production.

Acidification

The different whey composition affect the ricotta cheese production process: pH, protein and mineral content, the origin of the whey (breed), the animals feed, seasons of production, and the applied coagulation technique (Mucchetti and Neviani, 2006).

The pH values represent a salient parameter in ricotta production with a range from 6 to 5.8. The pH of whey during the heat denaturation of the proteins influences the ricotta cheese texture. Thus, the pH values close to neutrality during heat coagulation will result in a more
elastie structure of the product, whereas the pH leaning to acidic values will give a grainier structure. Moreover, according to Modler (1988) the α-LA is subjected to major denaturation at higher pH values.

Whereas ovine and caprine whey proteins are easily heat coagulated also at the natural pH of milk (normally at a pH of about 6.50) without exogenous acidification (Salvatore et al., 2014), cow and buffalo whey could be slightly acidified (Mucchetti et al., 2017). In some production systems to promote protein aggregation, synthetic acidulants are used (e.g., citric acid, lactic acid, magnesium sulfate; Mucchetti et al., 2017; Paskaš et al., 2019). The type of acidulant to promote flocculation is one of the most relevant processing factors in ricotta cheese production, and several factors should be considered for the correct precipitant, including availability, cost, curd characteristics, yield, and flavor (Weatherup, 1986; Modler and EmmONS, 1994).

The studies conducted to date have evaluated ricotta cheeses obtained with a single coagulating agent or comparing different coagulants with variable results. Araque et al. (2018) reported that the use of citric acid as a coagulant in the ricotta production decreased moisture, firmness, and yield, whereas the use of calcium chloride produced a white product with desired firmness and high consumer acceptability. Also, Rathnayake et al. (2019) reported that the addition of citric acid gave a low yield to ricotta cheese compared with acetic acid. El-Sheikh et al. (2010) found that ricotta cheese, made with whey protein concentrate, treated with citric acid had higher cheese yield, higher viscosity and best organoleptic quality characteristics compared with those made with Glucono-Delta-Lactone. Ricotta cheese made from sweet or salted whey produced by steam into the whey.

Heat Treatments

Temperature is a fundamental parameter throughout the ricotta production process to obtain the protein agglomerates, as well as the mode and speed of heating of the whey, which influences the aggregation phase of the whey proteins and final yield.

The range of temperatures in ricotta cheese production vary from 75 to 90°C depending on the type of whey (e.g., sheep whey 75°C, cow whey 85°C, or buffalo whey 90°C). The high temperature maintained by ricotta flakes at the surface for few minutes makes the curd network more firm and cohesive, facilitating the separation. In addition, the size of the protein agglomerates is important for the final structure of the product and to facilitate the scotta drain from ricotta. However, as temperature is increased, the higher is the α-LA denaturation and the ricotta yield, resulting in a product with a grainier and sandier structure and less moisture and smoothness (Mucchetti et al., 2017).

Heat treatment with a temperature higher than conventional pasteurization temperature is responsible for the formation of whey protein aggregates via thiol-disulfide interchange reactions and hydrophobic or electrostatic attractions (Donato and Guyomarc’h, 2009). Moreover, prolonged heating above 90°C brings to more than 70–80% denaturation and aggregation of whey proteins with κ-CN (Corredig and Dalgleish, 1996). The α-LA contained in the whey has a greater resistance to thermal denaturation and sustains up to 95°C (Singh and Havea, 2003) and its interaction with β-LG enhances the denaturation (Dalgleish et al., 1997).

There are different heat treatment techniques on which the rate of temperature rise depends. Usually, the traditional heat system provides an indirect supply of heat, using the steam from the double bottom boilers or the wood fire, with a higher yield of ricotta and a protein agglomerate with a great ability to drain scotta whey (Weatherup, 1986). However, these systems are lower, in terms of time, than the direct injection system of steam into the whey.
Recently, Shelke et al. (2022) observed that the heat-treating increase in ricotta cheese production resulted in a final product with high acceptability. In particular, different temperatures (85, 90, and 95°C) and holding times (10, 20, and 30 min) were compared, showing that the heat treatments at 95°C for 10 min resulted in a final product with great spreadability, shiny appearance, buttery flavor, color consistency, creaminess, curdiness, granularity, Cheddar whey aroma, acid taste, and uniformity. It was also observed that as the severity of heating increased, the moisture, recovery of protein, yield, and overall acceptability also increased and were highest at 95°C (Shelke et al., 2022).

Literature shows the possibility to use other treatments as the use of high pressure, which was tested in the ricotta production technology and compared with the traditional heat system. The products obtained after pressurization at 400 MPa for 30, 45, and 60 min have shown a lower yield and hardness but a higher cohesiveness than traditional ricotta cheese, and also had more homogeneous granulometric profiles (Besbes et al., 2002). Results of the study also revealed the microbial inactivation and the preserved nutritional and sensory properties of the ricotta cheese.

Thus, high pressure could represent a potential technology for a high-quality product. However, the high cost makes this technology not suitable for artisanal cheesemakers but it refers to industrial production, with a large volume of production.

Salt Addition

The use of salt represents another important factor in ricotta production, with the exception of some artisanal productions increasing the interactions with negatively charged proteins, thus improving aggregation. In an environment with ionic strength <20 mM, particularly in the absence of calcium ions and with pH >6.5, the charge repulsion between the whey proteins prevents aggregation, even if the percentage of denaturation is >95% (Mucchetti and Neviani, 2006).

The addition of salt in the mixture also had a significant effect on flavor, texture, color, and overall acceptability of the final cheese product (Kamel et al., 2013).

Adding NaCl during ricotta production, to whey and milk blend, increases the interactions with negative charged proteins and improves aggregation (Mucchetti et al., 2017).

The concentration and the type of salt can alter the aggregation and the gelling proprieties of whey proteins (Bowland et al., 1995). Moreover, Verheul et al. (1998) demonstrated that the whey protein gels became coarser with more prominent pores and a substantial increase in gel permeability when the NaCl concentration was increased. Factors that are sensitive to high NaCl levels and that might determine the structure of the whey protein gels are the kinetics of the denaturation and aggregation process and the solvent quality (Verheul et al., 1995).

Milk Addition

The raw materials used in the ricotta cheese manufacture can influence the characteristics of the product, and in particular can affect processing and yield. For instance, the protein concentration and also the processing conditions of the main ingredients (milk, whey) seem to be important parameters that can affect the quality of the ricotta cheese.

During production whey could be enriched with whole milk or cream (5–15%) and salt (0.5–1.5%; Man cuso et al., 2014), and the resulted blend originated a softy ricotta with a wet appearance and low hardness (Borba et al., 2014).

Various differences were found in ricotta cheese made with different milk fat content (<0.1, 1.5, and 3.0%) on the yield (ca. 12, 9, and 8% for full-fat, reduced-fat, and fat-free ricotta), composition, physical, chemical, and sensory properties. The increased yield of full-fat ricotta was due to both more elevated level of total solids in the raw milk and a higher recovery of milk solids. Fat-free ricotta was harder, whiter, and received the lowest acceptability scores compared with the reduced-fat and full-fat ricotta, which showed no differences in acceptability, suggesting that fat content could be considerably reduced without affecting cheese sensory properties (Araque et al., 2018).

Salvatore et al. (2014) studied how the whey protein concentration by ultrafiltration technique, a membrane separation process used to produce whey-protein concentrates, can affect the final yield of fresh sheep ricotta cheese. They found that during the production process the use of whey, concentrated by ultrafiltration, enhanced the extent of heat-induced protein aggregation. Each protein fraction presented a different behavior during heat-induced coagulation. In particular, the recovery of β-LG and α-LA in the cheese increased as their content increased in the whey mixture. The variations observed in relative abundances among whey proteins are linked to a change in the association behavior of α-LA with increasing concentration of whey proteins and a decrease in the ratio of calcium per protein. The study revealed that the availability of divalent cations (Ca^{2+} and Mg^{2+}) per protein was significantly reduced when the protein concentration in whey mixtures increased.

This caused a significant increase (P < 0.05) in the recovery of the protein fractions, particularly of α-LA,
and a subsequent increase in the final yield of the product. Ricotta cheese made from UF-whey protein concentrate and ricotta made from whey protein concentrate fortified with 2% skim milk powder showed the greatest organoleptic properties, including appearance, flavor, body, and texture, and high cheese yield (El-Sheikh et al., 2010). In another study, ricotta cheese made adding different concentration of skim milk powder and milk protein concentrate (2, 4, and 6%) showed acceptable values for the rheological properties (hardness, adhesiveness, cohesiveness, springiness, gumminess, and chewiness) and high total score points for sensory evaluation (Gomaa et al., 2015). Ricotta cheese was also manufactured by using the whey derived from mozzarella cheese production, which was condensed to a total solids content of 20.86%. This led to a better final yield of the product, a 4-fold increase compared with ricotta cheese obtained from noncondensed whey (Streiff et al., 1979).

RICOTTA CHEESE PRODUCTION TYPES: ARTISANAL AND INDUSTRIAL

Ricotta cheese production can be artisanal or industrial: the basic production methodologies are common for both, with some differences in the making process and in postprocessing treatment, which ensure different shelf-life.

Artisanal Production of Ricotta Cheese

Artisanal production of ricotta cheese today is referred to small traditional farms, with small quantities of production that ensure a representative quality product, strongly linked to the production areas, characterized by the use of natural ingredients and historical tools for production. The literature showed large variability in ricotta cheese production, especially in traditional systems, due to the use of different raw materials that vary according to the regional local uses and customs, with the exception of ricotta PDO that follows a production specification recognized by the EU Commission.

In some Italian productions the whey comes from traditional cheesemaking; for instance, in Sicily ricotta is traditionally manufactured from whey, obtained from the coagulation of the milk and the subsequent separation of the curd, after the production of hard semi-cooked cheese such as Pecorino Siciliano PDO, Piacentinu Ennese PDO, Ragusano PDO (cow, sheep, buffalo) at a temperature between 50° and 60°C, to increase the yield and improve the final characteristics of the product (Licitra et al., 1998; Filippetti et al., 2007; Mancuso et al., 2014). In the Ricotta di Bufala Campana PDO manufacture, up to 5% of fresh cream from buffalo whey is added (Tripaldi et al., 2020). Pala et al. (2016) reported that in Sardinian Ricotta Gentile (sheep whey) production milk and fine salt are added optionally to the whey having a temperature above 55°C. The whey, mixed with salt and milk, is heated from 80°C to 90°C, depending on the ricotta types, until the ricotta surfaces. However, to facilitate the ricotta cheese surface natural acidulants are added to the mixed whey as the use of ficara, fig latex mixed with water, in the production of artisanal ricotta informata (Campo and Licitra, 2006) or the addition of the cizza, a natural buffalo whey graft obtained from previous buffalo mozzarella cheese production, in the traditional Ricotta di Bufala Campana PDO production.

Moreover, after ricotta production, the scotta whey (deproteinized whey) is used for the second cooking of the cheese curd in Sicilian cheeses, including the PDO, and also used for the stretching of the curd during the production of the Provola dei Nebrodi PDO cheese (G.U.R.I., 2020), Vastedda della Valle del Belice cheese (G.U.R.I., 2010b), and Caciocavallo Palermitano cheese (Bonanno et al., 2013).

In Sardinia ricotta is typically produced with whey residue from the production of hard semi-cooked sheep milk cheeses such as Pecorino Romano PDO and Pecorino Sardo PDO (Spanu et al., 2017). Moreover, the traditional Ricotta di Bufala Campana PDO is manufactured according to the production protocol states of PDO cheese, from the PDO buffalo mozzarella cheesemaking (Tripaldi et al., 2020). Ricotta is also traditionally produced with whey resulting from the production of typical Malga cheese, a semi-skimmed hard cheese obtained from raw milk of highland pastures (Bergamaschi et al., 2016; Bittante and Bergamaschi, 2020).

After the curd separation ricotta is manufactured by heating whey, followed by optional ingredient additions. In artisanal method whey is warmed up in a traditional vat, whose name and manufacture varies according to the different areas. After reaching a temperature averaging 40 to 50°C whey can be enriched with sea salt, based on the local uses in different percentage from 0.4% to 1–2% (Campo and Licitra, 2006; Filippetti et al., 2007; Venusti, 2014; Tripaldi et al., 2020). Subsequently, a common practice in artisanal ricotta production is the addition of raw milk to the whey from 5% to 15%, depending on the types (cow, sheep, buffalo) at a temperature between 50° and 60°C, to increase the yield and improve the final characteristics of the product (Licitra et al., 1998; Filippetti et al., 2007; Mancuso et al., 2014). In the Ricotta di Bufala Campana PDO manufacture, up to 5% of fresh cream from buffalo whey is added (Tripaldi et al., 2020). Pala et al. (2016) reported that in Sardinian Ricotta Gentile (sheep whey) production milk and fine salt are added optionally to the whey having a temperature above 55°C. The whey, mixed with salt and milk, is heated from 80°C to 90°C, depending on the ricotta types, until the ricotta surfaces. However, to facilitate the ricotta cheese surface natural acidulants are added to the mixed whey as the use of ficara, fig latex mixed with water, in the production of artisanal ricotta informata (Campo and Licitra, 2006) or the addition of the cizza, a natural buffalo whey graft obtained from previous buffalo mozzarella cheese production, in the traditional Ricotta di Bufala Campana PDO production.

Campo and Licitra (2006) in the Sicilian production of Ricotta Iblea (cow whey) reported that flocculation...
begins at about 84°C. In the Sardinian production of Ricotta Gentile it takes place at a temperature of about 80°C (Venusti, 2014); Filippetti et al. (2007) reported that the surfacing of Ricotta Romana PDO starts from 85 to 90°C. Once the ricotta has fully surfaced, the foam on the surface is eliminated with a traditional spoon made of wood or steel named in different ways according to the production areas (e.g., in Sicily is called scumaricotta or in Sardinia spannarola). Subsequently, in all traditional manufactures, ricotta is manually picked up and placed in typical truncated-conical perforated baskets, called fuscella, which are placed on a board to drain scotta whey (Campo and Licitra, 2006; Filippetti et al., 2007; Venusti, 2014; Tripaldi et al., 2020). Then, the product is left to cool at room temperature before being transferred to the refrigerator and consumed within a few days. All the operations during the artisanal production, are carried out manually without the use of machinery or other automation, indicating the handcrafting of this production. Usually artisanal ricotta cheese is sold at the local level and the shelf-life is very short, much less than 1 wk, even under refrigeration conditions (Ricciardi et al., 2019). Artisanal production represents traditional manufacture strongly linked with the territories of production, in which several factors (natural ingredients, traditional tools, manual skills of the cheesemakers) play an important role in the production process, resulting in a large number of ricotta cheese varieties. The flowchart of artisanal production is summarized in Figure 1.

**Industrial Production of Ricotta Cheese**

The industrial production of ricotta cheese reported in literature showed several differences in the production phases, in temperatures and times and different ingredients used in different percentages. Usually, this kind of production is related to large-scale volumes,
with a large quantity of ricotta produced, and a standardization of the process and of the products.

In industrial ricotta cheese the whey usually derives from the production of industrial cheese made with pasteurized milk (e.g., crescenza or generic stretched cheeses). The whey is heated in large vats with different heating systems, such as injecting steam with low pressure (Paskaš et al., 2019), or using a plate heat exchanger (Toppino et al., 2004). Whey is enriched with milk (whole or skim), in the amount of 10%, and salt (1%), which are added at a temperature between 55 and 70°C according to different industrial processes (Piazza et al., 2003; Toppino et al., 2004; Paskaš et al., 2019). To promote protein aggregation, citric acid (Paskaš et al., 2019; Tirloni et al., 2019) or lactic acid (Piazza et al., 2003; Toppino et al., 2004) are added to the mixture (1.5–3%) at temperatures between 65 and 90°C. Moreover, in a study conducted by Hough et al. (1999) the addition of Streptococcus thermophilus starter to the whey was reported, at about 30° to 32°C, to increase the acidity. These additions can be substituted by the use of magnesium sulfate or other salts, which promote the modification of the mineral-protein interactions (Mucchetti et al., 2017).

In industrial production method ricotta starts to surface at about 80–90°C. Only Toppino et al. (2004) reported temperature of industrial ricotta surfacing at about 92–94°C. The high temperature maintained by ricotta flakes at the surface for some minutes makes the curd network more firm and cohesive, facilitating the separation. In addition, the size of the protein agglomerates is important for the final structure of the product and to facilitate the scotta whey drain from ricotta (Mucchetti et al., 2017).

When completely surfaced, industrial ricotta is collected into perforated molds to drain scotta and in the end hot-packaged, cooled, and stored at 3 to 4°C (Piazza et al., 2003; Toppino et al., 2004; Paskaš et al., 2019; Tirloni et al., 2019). To accelerate the collection process in industrial production, ricotta is picked up and put onto dripping cloths which in turn are folded into sacks and maintained in a suspended condition to complete the draining of the scotta whey (Magnarini et al., 1995). This process can be also mechanized (Modler, 1988). Paskaš et al. (2019) reported that after the ricotta collection in perforated molds the product was pressed at a temperature of 15 to 20°C for 20 min and salted at a temperature of 10 to 12°C, and finally, it was left to cool at low temperatures (4–10°C) for 6 to 12 h. Due to its reduced shelf-life at industrial level, ricotta cheese is generally heat-treated, whose process includes a final pasteurization step, assuring a shelf-life ranging between 20 and 40 d (Mucchetti and Neviani, 2006). Moreover, industrial fresh ricotta can be packed under atmospheric air or modified atmosphere conditions (30% CO₂ and 70% N₂; Spanu et al., 2017). Industrial production intends to produce on a large scale with a standardization of the process and the product. The flowchart of production is summarized in Figure 2.

**PHYSICOCHEMICAL QUALITY OF RICOTTA CHEESE**

A lot of studies have proved that ricotta cheese has a high moisture level (62–78%), high fat level (6–22%), good protein quantity (6–9%), with a low salt content (1%) except for the salted type (Table 2).

Several features can affect the physicochemical composition and markedly affect the final quality of the ricotta cheese including the type of raw materials (e.g., milk, whey), the season of production, the animal species and breeds, and the animal feed.

**Effect of Season**

Some studies showed that the seasonal changes had a significant effect on ricotta cheese characteristics. Acciaioli et al. (2009) evaluated how the season influenced the chemical and nutritive traits in ricotta cheese. The results of the study revealed that the season significantly affected the protein content of the product, with greater values in winter and spring, 26.69% and 26.28%, respectively (P < 0.05). Also, the ricotta cheese fatty acids (FA) content was influenced by season, especially in the summer with higher content of monounsaturated and polyunsaturated FA. The authors hypothesized that these results were related to the feeding regimen based mainly on fresh grass of pasture during the spring-summer period (Acciaioli et al., 2009). Also, Nudda et al. (2005) observed that the effect of the season in the ricotta sampling influenced all FA content, in particular, the highest content of CLA and vaccenic acid were detected in spring, with significant differences throughout the sampling period (P < 0.05).

**Effect of the Animal Species and Breeds**

The effect of breeds and species on the composition and, consequently, the quality of the dairy products, including whey and ricotta cheese, is well known in the literature, with a particular interest in the fat fraction, protein fraction and the sensory profile of the product. Pizzillo et al. (2005) reported that the FA profile of ricotta cheese was significantly affected by breed. Higher proportions of butyric (C4:0; 0.81%), capric (C10:0; 10.7%), lauric (C12:0; 6.49%), myristic (C14:00; 11.23%), palmitic (C16:0; 22.97%) acids were detected in ricotta cheese made from whey of local goat breed compared with other breeds (Girgentana vs. Siriana.
Ricotta cheese made from whey of Girgentana goats showed higher levels of monounsaturated and polyunsaturated FA (31.4 and 2.84%, respectively). Moreover, whey from milk of the Maltese breed reported a significantly lower content of dry matter compared with Girgentana and Syriana breeds (Pizzillo et al., 2005). Results of the research indicate that the breed affects the characteristics of the final product, usually with a positive effect on human health confirming how this genetic aspect affects cheesemaking technology and the quality of products. This also highlights how the local breed could represent an important presidio of the territories because strongly influence the production revealing products with remarkable features and uniqueness.

Krol et al. (2011) reported that the whey from the Jersey cows breed was characterized by the highest content of total protein including casein, whereas the whey from the Simmental cows breed showed significantly more whey proteins. Even, the simultaneous effect of breed and production season on whey protein content showed significant interactions ($P < 0.05$ and $P < 0.01$), and the simultaneous effect of feeding system and production season was also found on the whey protein content (Brodziak et al., 2012). Some studies revealed that also the sensory profile of ricotta cheese was influenced by breed and species. In particular the product made from Girgentana goat whey revealed greater softness and lower sensory score for granulosity, due to the high fat content ($64.56 \pm 3.73$ g/100 g of DM). Instead goat odor was more pronounced in ricotta made from whey of Siriana and Maltese goats ($P < 0.01$) due to the rate of fat hydrolysis (Pizzillo et al., 2005).

Miele et al. (2021) investigated the role of the whey origin on the typical sensory profiles of ricotta cheese, by comparing different samples made by buffalo, sheep and cow whey. According to this study, the 3 kinds of ricotta cheese were different from the sensory point of view. In fact, whereas cow ricotta samples were perceived sweet with an intense milk odor and a very high syneresis, sheep ricotta samples were less creamy and soft, with the darkest color, and the most intense ripened cheese odor. Both showed then peculiar sensory characteristics which allowed to easily distinguish each of them from the other ones. On the contrary, the water buffalo ricotta samples were perceived not
Table 2. Chemical composition of different ricotta varieties (mean ± SD)

<table>
<thead>
<tr>
<th>Product</th>
<th>Type</th>
<th>Time</th>
<th>Whey type</th>
<th>Manufacture</th>
<th>pH</th>
<th>Moisture (%)</th>
<th>DM (%)</th>
<th>Fat (%)</th>
<th>Protein (%)</th>
<th>Ash (%)</th>
<th>NaCl (%)</th>
<th>Lactose (%)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ricotta Pistoiese</td>
<td>Fresh</td>
<td>24 h</td>
<td>Sheep</td>
<td>Artisanal</td>
<td>6.23</td>
<td>74.18 (±0.78)</td>
<td>25.84</td>
<td>12.56</td>
<td>8.79 (±0.26)</td>
<td>—</td>
<td>1.05 (±0.12)</td>
<td>—</td>
<td>Mancuso et al., 2014</td>
</tr>
<tr>
<td>Ricotta Romana</td>
<td>Fresh</td>
<td>24 h</td>
<td>Sheep</td>
<td>Artisanal</td>
<td>6.53</td>
<td>70.03 (±3.72)</td>
<td>29.97</td>
<td>18.21</td>
<td>7.82 (±0.69)</td>
<td>0.53 (±0.14)</td>
<td>0.17 (±0.05)</td>
<td>3.74 (±0.30)</td>
<td>Mucchetti et al., 2002</td>
</tr>
<tr>
<td>Ricotta di Pecora</td>
<td>Fresh</td>
<td>24 h</td>
<td>Sheep</td>
<td>Artisanal</td>
<td>6.27</td>
<td>67.87 (±1.58)</td>
<td>32.13</td>
<td>20.74</td>
<td>6.67 (±0.02)</td>
<td>1.00 (±0.04)</td>
<td>3.71 (±0.03)</td>
<td>—</td>
<td>Pizzillo et al., 2005</td>
</tr>
<tr>
<td>Ricotta di Capra</td>
<td>Fresh</td>
<td>24 h</td>
<td>Goat</td>
<td>Artisanal</td>
<td>6.43</td>
<td>78.42 (±2.39)</td>
<td>21.58</td>
<td>11.67</td>
<td>6.63 (±1.16)</td>
<td>1.60 (±0.22)</td>
<td>—</td>
<td>—</td>
<td>G. Licitra, unpublished</td>
</tr>
<tr>
<td>Girgentana</td>
<td>—</td>
<td>—</td>
<td>Cow</td>
<td>Artisanal</td>
<td>6.51</td>
<td>72.87 (±1.58)</td>
<td>25.73</td>
<td>12.94</td>
<td>8.40 (±0.26)</td>
<td>—</td>
<td>0.74 (±0.10)</td>
<td>—</td>
<td>Tripaldi et al., 2020</td>
</tr>
<tr>
<td>Ricotta Vaccina</td>
<td>Fresh</td>
<td>—</td>
<td>Buffalo</td>
<td>Artisanal</td>
<td>6.24</td>
<td>55.14 (±6.14)</td>
<td>44.86</td>
<td>33.75</td>
<td>14.89 (±0.57)</td>
<td>1.19 (±0.01)</td>
<td>1.50 (±0.06)</td>
<td>2.5 (±0.29)</td>
<td>—</td>
</tr>
<tr>
<td>Saras del Fèn</td>
<td>—</td>
<td>—</td>
<td>Sheep/Goat</td>
<td>Artisanal</td>
<td>6.21</td>
<td>71.55 (±1.79)</td>
<td>28.45</td>
<td>11.13</td>
<td>10.36 (±0.12)</td>
<td>1.88 (±0.33)</td>
<td>0.20 (±0.12)</td>
<td>0.14 (±0.09)</td>
<td>Sarasso et al., 2019</td>
</tr>
<tr>
<td>Ricotta Mustia</td>
<td>Fresh</td>
<td>24 h</td>
<td>Sheep</td>
<td>Artisanal</td>
<td>6.51</td>
<td>74.55 (±1.79)</td>
<td>25.45</td>
<td>12.22</td>
<td>10.37 (±0.12)</td>
<td>1.11 (±0.33)</td>
<td>1.1 (±0.33)</td>
<td>1.1 (±0.33)</td>
<td>Scarano et al., 2019</td>
</tr>
<tr>
<td>Ricotta Forte</td>
<td>Fresh</td>
<td>24 h</td>
<td>Sheep</td>
<td>Artisanal</td>
<td>6.54</td>
<td>57.9 (±1.85)</td>
<td>42.13</td>
<td>19.55</td>
<td>14.84 (±0.81)</td>
<td>—</td>
<td>3.42 (±0.24)</td>
<td>—</td>
<td>Casti et al., 2016</td>
</tr>
<tr>
<td>Ricotta Infornata</td>
<td>Fresh</td>
<td>24 h</td>
<td>Sheep/Goat</td>
<td>Artisanal</td>
<td>5.52</td>
<td>47.8 (±7.57)</td>
<td>52.2</td>
<td>33.75</td>
<td>14.89 (±0.57)</td>
<td>0.93 (±0.43)</td>
<td>1.36 (±0.24)</td>
<td>1.76 (±0.24)</td>
<td>Gani et al., 2019</td>
</tr>
</tbody>
</table>

Effect of Animal Feed

An important aspect that influences the nutritional characteristics of ricotta cheese, especially the FA content, is the animal feed. Several studies, indeed, evaluated the effect of different diet on the quality of ricotta cheese, with possible benefits on human health.

The effect of diet on essential FA of ricotta was reported by Fusaro et al. (2019), who evaluated the FA profile of ricotta obtained from ewes fed 3 different diets, enriched with linseed, un-supplemented diet and pasture. Indeed, n-3 FA levels in ricotta from grazing sheep (1.1 ± 0.15 g/100 g of total FA) and from animals that received the diet enriched with linseed (2.83 ± 0.14 g/100 g of total FA) were notably higher than those that received un-supplemented feed (0.49 ± 0.17 g/100 g of total FA). The ricotta derived from linseed and pasture diet had lower concentrations of SFA (65.99 ± 1.23 and 65.04 ± 1.99 g/100 g of total FA) compared with the ricotta derived from un-supplemented diet (74.79 ± 1.23), higher proportions of CLA (0.63 ± 0.01 and 0.93 ± 0.05 g/100 g of total FA) and more favorable health indices. These results indicated that extruded linseed supplementation in dairy sheep may be a valuable nutritional strategy when pasture is not available (Fusaro et al., 2019).

Innossa et al. (2020) investigated the effect of dietary olive leaves supplementation in dairy goat on nutritional quality and FA profile of ricotta cheese compared with a conventional diet. Dietary olive leaves provided an increase of unsaturated FA such as vaccenic acid (C18:1 t11; 0.68 ± 0.07%), rumenic acid (C18:2 c9 t11; 1.19 ± 0.13%) and linolenic acid (C18:3 c9 c12 c15;1.16 ± 0.06%), and a decrease of n-6/n-3 FA ratio (3.25 ± 0.17%) in ricotta cheese. Moreover, ricotta cheese de-
rived from dietary olive leaves was also characterized by a higher content of polyphenol compounds and higher antioxidant capacity compared with ricotta cheeses derived from conventional diet. From the acquired results it was possible to highlight a favorable effect of olive leaf in the production of functional ricotta cheese, with a high health value (Innosa et al., 2020).

Seguel et al. (2020) evaluated the effect of supplementation with forage rape or summer turnip in the diet of dairy cows on the FA profile of blood plasma, milk, and cheese, and the organoleptic characteristics of Chanco and ricotta cheeses. A decrease in C20:5n-3 in ricotta cheese were found in the supplementation with brassicas. Overall the FA profile of ricotta cheese was similar to that of Chanco cheese, mainly because ricotta cheese was prepared from whey obtained from the Chanco cheese production. Similarly, in cows grazing summer highland pastures, Bergamaschi et al. (2016) found that milk, fresh cheese and ricotta cheese had similar contents of SFA, MUFA, and PUFA. Nudda et al. (2005) found that in sheep dairy products, the FA concentrations in fresh cheese and ricotta cheese depended mainly on the FA content of unprocessed raw milk.

Literature shows a large interest in the use of alternative feeds to meet the increasing needs, and ultimately to decrease the environmental footprint of animal products, obtaining products with desirable quality. In most cases, products with high nutritional characteristics were obtained. The use of sustainable animal feed thus could represent an important resource for farmers to overcome seasonal problems when pasture is not available, and for consumers to find a product with high nutritional quality.

**MICROBIAL PROFILE OF RICOTTA CHEESE**

Ricotta cheese, especially the fresh type, is a dairy product that could represent suitable conditions as a growth medium for a large variety of microorganisms, mainly due to the presence of nutrients, high water activity, high moisture level, high concentration of residual sugars, and a pH above 6.0 (Pintado et al., 2001; Pala et al., 2016).

However, it is important to highlight that the high temperatures reached by the whey during the ricotta production, represents a killing way for the growth of potential pathogens microorganisms (Scatassa et al., 2018). For these reasons the ricotta cheese microbiota consists of heat-resistant and postcontamination microorganisms whose presence could be prevented or reduced with second heat treatment of ricotta after the scotta drainage through the use of a heat exchanger at temperatures between 85 and 95°C, or by direct hot packing, immediately after the production (Mucchetti et al., 2002; Mucchetti et al., 2017).

Several microbiological analyses showed the presence of different microorganisms both in ricotta and in environments of dairy industries. A study conducted by Scatassa et al. (2018) on Sicilian ewe ricotta cheese collected from dairy factories in small and large distribution revealed the presence of Enterobacteriaceae (21%; 3.67 log cfu/g), Escherichia coli (13%; 3.20 log cfu/g), coagulase-positive staphylococci (2.19%; 1.56 and 5.38 log cfu/g), and Bacillus cereus (16%; 3.79 ± 0.95 log cfu/g). The level of contaminants did not lead to significant toxin production (EFSA BIOHAZ Panel, 2016). The presence of pathogenic bacteria such as Listeria monocytogenes, Salmonella spp., and Brucella spp. was never discovered. Values above the average reported by these authors were found by Bellassi et al. (2021) who studied the chemical, microbiological, and sensorial changes of the ricotta cheese made with a 30% milk cream during its shelf-life period (12 d). Overall microbiological analysis revealed a significant trend in the growth of degradative bacteria, including Enterobacteriaceae and Pseudomonadaceae, in ricotta during shelf-life.

Guatemim et al. (2016) evaluated the microbiological quality of industrial ricotta commercialized in the western region of Santa Catarina State (Brazil) and found that the 33.3% of the samples were not suitable for human consumption because they were contaminated with thermotolerant coliforms.

The microbiological profile of Ricotta Romana PDO cheese showed a good hygienic condition of the product with an average total microbial count of 5.4 log cfu/g, E. coli 1 log cfu/g, coliforms 2.4 log cfu/g, coagulase-positive staphylococci 3.05 log cfu/g, and Salmonella spp. and Listeria monocytogenes have never been identified. These results revealed a good hygienic condition of product; indeed, all the samples comply with the laws in force (European Commission, 2005; Filippetti et al., 2007). Industrial cow ricotta samples collected at retail markets showed a large variability of microbiological characteristics (from <3 log cfu/g to more than 6 log cfu/g). Lactobacillus and enterococci (<10 cfu/g) were the most represented microbiota. Bacillus spp. and Clostridium spp. were not detected in more than the 40% of the samples, while the highest count was less than 3 log cfu/g (Mucchetti et al., 2002).

Fadda et al. (2012) observed ovine ricotta, collected in Sardinia, with a prevalence of Bacillus cereus (50%), Enterobacteriaceae (23%), and E. coli (12%). The results suggested that maintaining the cold chain in the production process could prevent the risk from the contamination of Bacillus cereus, and improve the hygienic conditions of the processing plant, tools, and personnel.
to reduce the risk of recontamination by Enterobacteriaceae and E. coli.

Different studies revealed that from a microbial and hygienic viewpoint, ricotta, due to its characteristics, is an excellent substrate for the potential growth of undesirable microorganisms, revealing the presence, even if few, of a population of spore-forming bacteria, or pathogens, such as Listeria monocytogenes or Bacillus cereus, due to postheating contamination usually correlated with low hygienic conditions and possible biofilm formation (da Silva Fernandes et al., 2014; Tirloni et al. 2019).

Immediately after production, ricotta cheese is a safe product, without any undesirable microorganisms, and this is related to the high temperatures applied during production that inactivates the growth (Puccio et al., 2022).

However, although the product’s microbiological characteristics could depend on the environmental contaminants and the hygienic conditions after the production process (postcontamination), the implementation of these aspects can improve the production and have stricter control on the product quality. Due to their resistance to pasteurization, ability to form biofilms, and persistent presence during ricotta processing, the control of these undesirable microorganisms in the processing plants is extremely important.

Literature showed several studies aimed to inhibit and control microbial growth without altering the original characteristics of the ricotta cheese and also extend the shelf-life. Second heat treatments are normally used to reduce possible microbial growth; nevertheless, new techniques were also applied that are discussed in the “New Trends in Ricotta Cheese Production Technologies” section.

**NEW TRENDS IN RICOTTA CHEESE PRODUCTION TECHNOLOGIES**

In recent years several studies conducted on ricotta cheese production evaluated how the use of different ingredients or new technologies influenced the characteristics of the products. Particular focus was addressed to the addition of health components and the application of alternative process technologies.

**Addition of Components**

Recently, the increased interest in the functional food sector has also involved ricotta production, especially in the use of prebiotics or probiotics that can provide basic nutrition and promote health, and to develop novel food products. Niro et al. (2013) observed the addition of probiotic strain L. paracasei ssp. paracasei F19 and 2 different prebiotics and inulin, after the production during the homogenization step, into ricotta cheese, as a food carrier for functional ingredients. The results revealed that the ricotta cheese samples maintained high counts (over 10^9 cfu/serving size) during the cold storage (5°C) without altering the nutritional and sensorial properties. Similarly, the addition of inulin did not significantly affect the sensory profile of the cheese. However, the combination of both altered the ricotta sensory characteristics, with a considerable decrease (P < 0.05) for taste pleasantness caused by an excessive acidification (Niro et al., 2013). In another study (Fritzen-Freire et al., 2013), the addition of Bifidobacterium BB-12 microencapsulated with inulin by spray drying in ricotta cream, during the mix-phase, cooled down (~45°C) and produced with reconstituted skim milk, showed an increase in the acidity (P < 0.05), total solids content (P < 0.05), adhesiveness (P < 0.05), and firmness (P < 0.05) throughout 60 d of storage (5 ± 1°C); color parameters showed high luminosity and a tendency toward a green and yellow color during the storage period; sensory analysis exhibited that the addition of Bifidobacterium BB-12 in the product sample resulted in good acceptability by consumers (Fritzen-Freire et al., 2013).

Sameer et al. (2020) demonstrated that incorporation of L. acidophilus La-05 during the homogenization of fresh buffalo milk ricotta cheese did not modify the compositional, textural, color, and sensory profile of the product with high overall acceptability (9.0 out of 10 scale) scores. Differently when incorporating into goat ricotta, L. acidophilus La-05 brings a homogeneous texture and a more acidic flavor, most likely associated with the concentration of lactic acid in the product.

In addition, Lopes et al. (2021) evaluated the effect of the addition of L. acidophilus La-05 probiotic culture as free cells (F), microencapsulated with alginate or microencapsulated with alginate coated with chitosan (ACM), on the quality parameters of spreadable goat ricotta cheese, after homogenization, during storage at 7°C. The resulting probiotic whey cheeses had higher yield (P < 0.05) and higher moisture content (P < 0.05) than the product without probiotic addition, which results in softer cheeses. The products with the incorporation of free or microencapsulated L. acidophilus were also less gummy, more cohesive and adhesive (P < 0.05), and more yellow than the product without probiotic. The spreadable goat ricotta cheese with microencapsulated probiotic cultures showed also volatile compounds with floral and fruity notes and lower goat aroma (Lopes et al., 2021).

Nzekoue et al. (2021) found that ricotta cheese constitutes a proper food matrix for phytosterols enrichment, which showed a good heat-stability in ricotta cheese.
cheese matrix during cheese homogenization process (87.0–89.7%). In addition, the functional ricotta cheese obtained showed a homogeneous phytosterols distribution which maintained their potential functionality in the product during its shelf-life (4 wk) without any significant variation of the total phytosterols levels during storage (4°C). Then the presence of phytosterols improved the nutritional benefits of ricotta (0.83 g of phytosterols for 100 g of ricotta), representing an interesting opportunity for consumers of ricotta cheese and individuals controlling their blood low-density lipoprotein cholesterol (Nzekoue et al., 2021).

A significantly higher angiotensin-I-converting enzyme (ACE)-inhibitory activity was found in the ricotta cheese fortified with fermented ultrafiltration protein-rich retentate (R-UF) using Lactobacillus helveticus strain as a starter, as compared with the samples without this treatment. The fermented R-UF was spray-dried to the ricotta cheese at different fortification levels (1 and 5% wt/wt). In particular, the 5% fortification level brought to high levels of bioactive peptides (ca 30 mg into 100 g of product), medium acidification (pH 5.2 ± 0.2), increased hardness, and chewiness, decreased the milk odor, and improved flavor persistence and sapidity taste of the ricotta cheese. The ricotta cheese enrichment in antihypertensive bioactive peptides represents a readily scalable process that could be used as a novel treatment for the design of innovative functional ricotta cheese with positive effects on human health (Pontonio et al., 2021).

Siyar et al. (2022), to obtain a novel functional food, examined the effect of the addition of the encapsulated saffron extract with different soy lecithin concentrations, to the ricotta cheese. The results showed that the fortification of cheese with encapsulated saffron extract with liposomal extract did not have any negative effect on the chemical composition and color of ricotta cheese, especially the lower pH (5.39 ± 0.01) and higher hardness and chewiness (P < 0.05), compared with the sample without saffron extract enrichment. Another functional ricotta cheese was developed by Zinina et al. (2021) who tested the addition of dietary fiber in different amounts (1, 3, and 5%) during ricotta production. The results showed that with the addition of citrus dietary fiber at 5%, the fat content decreased (5.02), the moisture content (65.88%) increased, and the yield also increased. The results of descriptor analysis showed that with the addition of dietary fiber, the product develops a citrus smell and taste, with a denser texture. The study revealed the possibility of introducing citrus dietary fiber as a functional ingredient into ricotta cheese. Ricotta cheese represents an excellence of gastronomy in Sicily, especially the ewe type, and is typically used as a topping ingredient for dressing pastas and especially to prepare several Sicilian desserts and confectioneries. For this reason, it was formulated as a sugar-added cream ricotta cheese, usually frozen and ready to use. Sugar-added ricotta is made from fresh ricotta with the addition of 40% (wt/vol) fine white sugar and subsequently passed through a smoothing-homogenizing machine to obtain a homogeneous creamy product. Finally, the ricotta formulation was packaged into 3-layer coextruded plastic film sac à poche bags, hermetically sealed and stored at 4°C (Puccio et al., 2022). The study conducted on sugar-added ricotta cheese demonstrated that the addition of 40% sucrose determined stability of all parameters, but the bacterial counts indicated that the shelf-life cannot be longer than 40 d, leading to the possibility to export and enhance the use of sugar-added ricotta for the Sicilian confectionery industry and to produce Sicilian desserts outside Sicily.

Regarding the use of several ingredients in the post-processing ricotta, including healthy and sweet components, the literature shows a great interest in these productions. Nevertheless, it is not easy to find these innovative products in the market, except for the sugar-added ricotta cheese, which is used in several sweet productions both by pastries and consumers. The problem may be related to the low knowledge of these kinds of ingredients by the dairy industry, and at the same time, these innovative productions are related to industrial production and not to artisanal production, whose unique application could be represented by the sugar addition. Additionally, in artisanal production, the low quantity of product makes this novel application less suitable. On the contrary, the big volume quantity of ricotta produced at the industrial level could be more intended for these novel applications.

**Alternative Treatments**

In recent years, due to the high interest of industrial production, different treatment and technologies in the ricotta making process were conducted to improve and evaluate the behavior on the different characteristics of the product. To prolong the ricotta shelf-life without using thermal treatments, Ricciardi et al. (2019) proposed the use of x-ray treatment on artisanal and industrial fresh ricotta cheese. In particular for the artisanal product, the shelf-life of the sample treated at 0.5 kGy x-ray irradiation reached 14 d of storage, whereas samples treated at 2 and 3 kGy remained acceptable for more than 20 d.

The industrial product, subjected to thermal pasteurization, reached a shelf-life of about 40 d even without any treatment, whereas x-ray-treated samples recorded a significant shelf-life prolongation, up to 84 d without
any changes on the microbiological and sensory characteristics. The study highlights the great efficacy of X-rays to sanitize and prolong the shelf-life of the product.

Another technology used to prolong shelf-life of ricotta cheese, overcoming the use of thermal sterilization without altering the proprieties of the product, was UV light. Ricciardi et al. (2020) revealed that the effectiveness decontamination properties of UV-C and near-UV-visible light treatments affected microbial proliferation and controlled sensory deterioration with comparable efficacy on ricotta cheese, with a shelf-life extension.

Also, pulsed light was assessed on microbial inactivation, sensory proprieties, and protein structure of fresh ricotta cheese, demonstrating that this treatment could be used to decontaminate the surface of ricotta cheese, potentially allowing the extension of its short shelf-life. With ricotta cheese being a protein-rich food, pulsed-light treatments exceeding a given radiant exposure could promote intense quality depletion, mainly associated with photo-induced modification of proteins (Ricciardi et al., 2021).

The shelf-life enhancing of both artisanal and industrial ricotta cheese represents a fundamental element for a large-scale ricotta market at both the national and international level, justifying continued research for new strategies to prolong and preserve the shelf-life of the products (Ricciardi et al., 2019). The literature reveals a great interest to find nonthermal sanitization techniques in ricotta cheese without altering the nutritional value, flavors, colors, or texture of the final product.

At the industrial level the application of these techniques could represent an important way to improve the trade, reaching international destinations, whereas the artisanal productions, normally entrusted to small dairies, do not have the economical possibilities to apply these innovative technologies.

Tripaldi et al. (2020), in a study with the aim to evaluate how to extend the shelf-life of buffalo ricotta cheese, evaluated second heat treatments followed by homogenization technology using a homogenizer-smoother machine in which the product reaches pasteurization temperatures (65°C/30 min), expected by the PDO product specification (G.U.R.I., 2010a). The homogenization process with low pressure was used to inhibit the syneresis of scotta whey from the product, which allowed the extension of shelf-life of ricotta cheese to 3 wk.

CONCLUSIONS

Ricotta cheese represents an original by-product for whey enhancement, with Italian origins, according to different historical sources, but also produced and appreciated in other countries. This confirms the large number of varieties of ricotta produced and reported in this work. The review shows the mechanism of production of ricotta cheese, the different parameters that affect the final characteristics of the product, and also the main differences between the artisanal and industrial production. The need to improve the characteristics of the product and to enhance in the market a product with positive effects on health led to developing a lot of fortification systems, by the use of bioactive compounds, to ricotta cheese to formulate new healthy functional food. However, it is still difficult to find on the market this kind of ricotta formulation. Sugar-added production could represent an interesting way to formulate and sell this dairy product. Another important aspect focused by the research was to find sanitization techniques, increasing the shelf-life of fresh ricotta without changing the quality, representing an important way to improve the trade and reaching international destinations.

Thus, throughout the different studies reviewed, it was possible to highlight the great interest by the cheese industries and by the research for this by-product, which requires still attention, especially for the artisanal manufactures locally produced. In particular, further studies need to characterize the chemical and sensory profile of the artisanal product and the experimentation of novel technologies accessible to small dairies that allow enhancement of their production.

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