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ORIGINAL RESEARCH

# Diversity of traditional Caciocavallo cheeses produced in Italy

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*This paper presents the results of a survey carried out in 68 dairies in southern Italy on the manufacturing processes of traditional Italian Caciocavallo cheese varieties. Following a study of the relevant literature, the various cheesemaking processes were analysed and the implications of different cheesemaking procedures were explored. The manufacturing variations able to influence the organoleptic characteristics of Caciocavallo cheese were milk and rennet types, procedures for curd acidification and stretching, salting and ripening conditions, and smoking treatment. This survey is designed to guide producers and consumers alike with respect to the perceivable effects of manufacturing variants on cheese quality.*

**Keywords** Italian Caciocavallo cheese, *Pasta Filata*, Cheese manufacturing variations, Traditional food products.

## INTRODUCTION

As a result of different environments, cultures and a rich history, several cheese varieties are produced in Italy according to local traditions. One of these is Caciocavallo, a *Pasta Filata* cheese type traditionally manufactured all over southern Italy, to such an extent that it is also known as the cheese of the *Kingdom of the Two Sicilies*, a large area stretching from central Italy to the island of Sicily that existed until Italy was unified in 1861. Worldwide, there are many Caciocavallo-like cheeses, known as *kaskaval, kaşar, kasseri* etc., produced over a large area embracing the Crimea, the Caucasus, the Balkans, North Africa and Italy (Carić 1999). Since Italian Caciocavallo is traditionally made in small-scale artisanal dairies and is mainly sold on local markets, its current production cannot be exactly quantified. Despite the long tradition and established consumer interest, only two varieties are labelled as Protected Designation of Origin (PDO), namely Caciocavallo Silano (IT/PDO/0117/000) and Ragusano (IT/PDO/0017/1505). There is no protection of the generic designation 'Caciocavallo', and cheeses of similar manufacture are marketed under the same name (Piraino *et al.* 2005). Common features of such cheeses are medium size (on average 2 to 3 kg), typically oval-shaped with a small ball on top (but sometimes also in the shape of a parallelepiped), ripening time usually shorter than six months (but longer times until 24 months are not infrequent), medium moisture level (35%–55%), medium–hard texture, homogeneous body with few small eyes or none at all, a more or less intense yellow colour according to animal feed and ageing, and a sweet taste that tends to be piquant with ripening (Carić 1999; Piraino *et al.* 2005).

The manufacturing process of Caciocavallo can be divided into two main phases, namely curd formation and stretching of acidified curd, to which forming, salting and ripening are added to complete the production cycle (Figure 1). Briefly, milk is gently heated to 36–38 °C, possibly inoculated with a starter culture and coagulated by rennet. When curd reaches proper consistency (30–40 min), the coagulum is cut into fine particles (6–8 mm), the whey is

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partially removed, and the fresh curd is left to acidify under heated whey or on a table. Then, ripened curd is manual stretched and shaped. Finally, the cheeses are cooled in water, salted in brine and then left to ripen. Due to the high artisanal degree of production, variations in the cheesemaking process can be found among cheeses produced in different areas (Piraino *et al.* 2005). Although some specific aspects of single Caciocavallo varieties have been examined by a large body of literature, as reported throughout this paper, no study has surveyed the differences in the various cheesemaking processes.

Consumers interested in traditional food assign greater importance to taste and typicality of food products (Guerrero *et al.* 2009; Vecchio *et al.* 2016). Thus, this study provides a focus on the manufacturing variations found in the Italian Caciocavallo varieties and aims to compile and discuss the main aspects able to influence the organoleptic characteristics of the product.

## MATERIALS AND METHODS

The first step in this survey required the inclusion criteria to select the artisanal varieties of Caciocavallo to be established. Since consumers of traditional foods are receptive to label signalling food origin (Hu *et al.* 2012), it was chosen to consider only products included in the list of *Traditional Agri-Food Products* (TFP) by the Italian Department for Agriculture. These products are characterised by processing and ripening methods that are consolidated in a given area for at least 25 years according to uniform and constant local use. In many cases, such production supports the local agricultural economy, thereby protecting rural areas from depopulation (Guerrero *et al.* 2009). The application of this screening criterion also ensured the selection of cheeses with a noteworthy production level, for which environment and local use may play a key role in determining properties, but whose cheesemaking protocol is not mandatory, as it is in PDO products. This step results in selecting 23 TFP Caciocavallo cheeses listed in Table 1.

The second step in this analysis, which is the subject of this report, identified the manufacturing variations able to differentiate the Caciocavallo varieties. For this purpose, a confidential survey was conducted from April to June 2017, during which four small- to medium-scale dairies for each TFP Caciocavallo were visited or contacted and were asked to describe their cheesemaking procedure, including brining and ripening methods. For 12 varieties with a limited production, only two dairies were contacted (Table 1). The producers were provided by the local provincial agricultural extension offices (STAPA CePICA). Producers' participation was voluntary. Overall, the survey covered 68 dairies.

## RESULTS

Although the production area of several Caciocavallo cheeses encompasses one or more Italian districts, almost half of the surveyed cheeses were produced in a very restricted area, often limited to a small town or village, which indicates a close link of these products to their territorial identity (Fonte, 2008) (Table 1). The survey highlighted large variations in cheesemaking procedures even within the same cheese variety, as is frequent in traditional

Gently heating raw milk (38–45°)
↓
Natural Acidification (raw milk microbiota or natural whey culture from previous cheese making)
↓
Rennet addition
↓
Curd cutting at 6–8 mm
↓
Maturation of curd
↓
Curd stretching by hand
↓
Shaping
↓
Brine salting
↓
Drying
↓
Ripening

**Figure 1** Flow diagram of Caciocavallo cheesemaking process.

**Table 1** Cheesemaking processes and production areas of the Italian Caciocavallo cheeses labelled as Traditional Food Product.

| *TFP Caciocavallo* | *Production area and milk origin* | *Inoculation* | *Type of Rennet* | *Stretching* | *Curd acidification* | *Ripening time and treatments* | *Salting in brine* |
|---|---|---|---|---|---|---|---|
| C. from buffalo milk, Campania† | Naples, Caserta, Salerno provinces in Campania<br>Water buffalo | DWC | Lamb paste | Hot water | The whey is drained and the curd is left at room temperature | At least 60 days | 18%–24% NaCl for about 6 h/kg |
| C. from buffalo milk, Lazio† | Rome, Latina and Frosinone Districts in Lazio<br>Water buffalo | NWC | Lamb liquid or paste | Hot water | The whey is drained and the curd is left at room temperature | At least 3 months. Can be smoked | 18%–24% NaCl for about 6 h/kg |
| C. di Ciminà‡ | Ciminà and Antonimina, small towns in Calabria<br>Brown, Red spotted, Podolian cattle milk mixed with ewe or goat milk (5%–10%) | RMM | Kid paste | Hot water | The whey is drained and the curd is left at room temperature | It can be consumed after a few days or after 1 month ripened in cellar or fresh environment | 22%–25% NaCl for about 6 h/kg |
| C. Podolico Dauno† | Puglia Region<br>Podolian cattle | NWC | Calf liquid | Whey | The whey is drained and the curd is left at room temperature | From 2 months to 3 years and more | 15%–30% NaCl for about 12 h/kg |
| C. Podolico of Campania Region† | Avellino, Caserta and Salerno provinces in Campania<br>Podolian cattle | DWC<br>RMM | Calf liquid, Lamb paste, Kid paste | Hot water | Under scotta | From 3 months to 1 year | 20%–22% NaCl 20 h/kg |
| C. Podolico of Basilicata‡ | Podolian cattle | NWC | Calf liquid, Lamb paste, Kid paste | Hot water | Under scotta | From 2–3 months to 1 year | 18%–20% NaCl for about 12 h/kg |
| C. Podolico of Calabria Region‡ | Cosenza and Catanzaro Districts in Calabria Region<br>Podolian cattle | RMM | Calf liquid, Lamb paste, Kid paste | Whey | Under whey | At least 3-6 months to 3 years and more | 18%–22% NaCl for about 12 h/kg |
| C. of Matese Mountains† | Matese Mts. in Campania<br>Brown, Red spotted cattle | NWC | Calf liquid or paste | Whey | Under whey | It can be consumed fresh (from 20 to 30 days), dull (until 3 months) and aged (from 7 to 18 months and more) | 8%–20% NaCl for about 12 h/kg |

(continued)

**Table 1** (Continued).

| *TFP Caciocavallo* | *Production area and milk origin* | *Inoculation* | *Type of Rennet* | *Stretching* | *Curd acidification* | *Ripening time and treatments* | *Salting in brine* |
|---|---|---|---|---|---|---|---|
| C. of Abruzzo Region† | Abruzzo Black and White, Brown, Red spotted cattle | NWC RMM | Calf liquid | Hot water | Under whey | From 3 to 1–2 years | 8%–20% NaCl for about 16 h/kg |
| C. of Tanagro caves‡ | Tanagro Valley, province of Salerno in Campania | RMM | Lamb paste, Kid paste | Hot water | Under scotta | From 3 to 24 months, in caves | In brine (27%–30% NaCl) at room temperature for about 8 h/kg |
| C. of Supino‡ | Supino, a small town in Lazio Black and White, Brown, Red spotted cattle | RMM | Calf paste | Hot water | Under whey | From 15 d to 1–2 months | 20%–22% NaCl for about 6 h/kg |
| Smoked C. of Campania† | Campania Black and White, Brown, Red spotted cattle | DWC NWC | Lamb paste, Kid paste | Scotta | The whey is drained and the curd is left at room temperature | From 2 to 12 months. Can be ripened in caves or smoked by using straw | 15%–18% NaCl for about 6 h/kg |
| C. palermitano† | Palermo and Trapani provinces in Sicily Brown, Red spotted, Cinisara cattle | RMM | Lamb paste | Whey, Scotta | The whey is drained and the curd is left at room temperature hanging on a stick | From 3 to 4 months | 18%–26% NaCl for about 24 h/kg |
| C. pugliese† | Puglia Black and White, Brown, Red spotted cattle | NWC MNC | Calf liquid | Hot water | The whey is drained and the curd is left at room temperature | At least 2 months | 18%–20% NaCl for about 12 h/kg |
| C. Vaccino of Lazio Region† | Viterbo, Frosinone and Rieti provinces in Lazio Black and White, Brown, Red spotted cattle | MNC | Lamb paste | Whey | The whey is drained and the curd is left at room temperature | From 1 to 12 months. Can be ripened in caves or smoked by using straw | 18%–20% NaCl for about 6 h/kg |
| C. Irpino ripened in caves‡ | Irpinia mountains in Campania Brown and Red spotted cattle | DWC NWC | Calf liquid or paste | Hot water | Under whey | For 45-60 d in caves | First step: 12%–14% NaCl at 20 °C for about 5 h/kg. Second step: 16%–18% NaCl at 15 °C for about 3 h/kg |
| C. of Molise† | Molise Region Black and White, Brown, Red spotted cattle | NWC | Lamb paste or Kid paste | Whey | Under whey | At least 3 months | In brine (18%–24% NaCl) at room temperature for about 6 h/kg |

(continued)

**Table 1** (Continued).

| *TFP Caciocavallo* | *Production area and milk origin* | *Inoculation* | *Type of Rennet* | *Stretching* | *Curd acidification* | *Ripening time and treatments* | *Salting in brine* |
|---|---|---|---|---|---|---|---|
| C. of Castelfranco‡ | Castelfranco Miscano, a small town in Campania Black and White, Brown, Red spotted cattle | DWC RMM | Calf liquid or paste | Hot water, Scotta | Under whey or scotta | From 3 to 24 months | In brine (22%–25% NaCl) at room temperature for about 12 h/kg |
| C. of Agnone‡ | Agnone, a small town in Molise Black and White, Brown, Red spotted cattle | NWC | Lamb paste, Kid paste | Hot water | Under whey | In natural caves for at least 3 months | In brine (20%–22% NaCl) at room temperature for about 6 h/kg |
| Gran Cacio of Morolo‡ | Morolo, a small town in Lazio Black and White, Brown, Red spotted cattle | NWC | Calf liquid or paste | Hot water | The whey is drained and the curd is left at room temperature | From 10 to 18 months. Smoked by using beech chips | In brine (22%–24% NaCl) at room temperature for about 12 h/kg |
| Casucavaddu Ibleo‡ | | RMM | Lamb paste, Kid paste | Hot water | The whey is drained and the curd is left at room temperature | From 2 to 6 months. | In brine (18%–26% NaCl) at room temperature °C for about 24 h/kg |
| C. of Cervati caves and Pertosa gorges‡ | Tanagro Valley of river and the all area of Cervati and Alburni Mts, Salerno province in Campania Podolian, Brown, Red spotted cattle | RMM | Kid paste | Hot Water | The whey is drained and the curd is left at room temperature | From 3 to 24 months, in caves | In brine (27%–30% NaCl) at room temperature for about 8 h/kg |
| C. of Maratea‡ | Maratea, a small town in Basilicata Black and White, Brown, Red spotted cattle | NWC | Calf, liquid or paste | Hot Water | The whey is drained and the curd is left at room temperature | It can be consumed after a few days or after 2 months' ripening in a cellar or fresh environment. | In brine (18%–20% NaCl) at room temperature for about 8 h/kg |

TFP, traditional food product; DWC, deproteinised whey culture; NWC, natural whey culture; RMM, raw milk microbiota; MNC, milk natural culture.
*Data from 4 farms.
†Data from 2 farms.

cheeses produced in small-scale dairies (Esposito *et al.* 2014). Consequently, we focused on the main variants that, on the basis of the literature discussed throughout the paper (e.g. Farkye, 2004), are able to influence the characteristics of Caciocavallo perceivable by consumers, that is milk used, rennet type, methods of curd acidification and stretching, salting procedures, ripening conditions and, when relevant, smoking treatment.

## Milk type and treatment

The surveyed Caciocavallo varieties were produced mostly from cows' milk. Two varieties were made with milk from the Mediterranean water buffalo (*Bubalus bubalis*) and were produced in the regions of Campania and Lazio, where about 90% of the Italian buffalo population is concentrated (Sannino *et al.* 2017, 2018), almost exclusively for milk production (Masucci *et al.* 2016; Serrapica *et al.* 2018).

In most other cases, the milk used was from various breeds, mainly Black and White and, in hilly and mountainous zones, Brown and Red spotted cattle (Table 1). *C. Podolico* was produced exclusively from milk from Podolian cattle (as purebred or crossbreed), while one dairy produced *C. del Matese* by using only milk from Brown cattle. As an exception, *C. di Ciminà* was produced by mixing cows' milk with 5%–10% of goats' or, a less usual alternative, ewes' milk. All varieties were produced by using raw milk, except the dairies producing *C. Podolico* from Basilicata which used a mixture of raw and heated milk (50–60 °C).

**Rennet type**

Animal rennet from various species (calf, kid or lamb) and in different forms (liquid or paste) were the coagulants used. Fifteen varieties used a specific rennet, whereas the others employed more than one type. Two dairies producing the *C. of Cervati caves and Pertosa gorges* (Table 1) stated that they used artisanal kid rennet.

**Starter microbiota**

Commercial starter cultures were not employed in any Caciocavallo-making procedure, whereas all kinds of artisanal cultures were detected, namely milk culture (2 varieties), whey-starters (8) and deproteinised whey-starters, the so-called *scotta*, that is deproteinised whey left over from Ricotta cheese production (4). Two varieties were produced by using more than one natural culture, whereas eight were produced without recourse to any starter cultures, with milk acidification exclusively relying on raw milk microbiota.

**Curd acidification**

Curd acidification was carried out under whey (8 varieties) or under *scotta* (4), but in eleven varieties the whey was entirely drained and curd was left to acidify on a surface or hung on sticks (*C. palermitano*). Wooden equipment (mainly vats, spines for rupture and curd maturation, shelves) was found in all the cheesemaking procedures examined. In particular, wooden utensils, especially vats, were always used to produce the eight varieties manufactured without natural starter cultures; for the others, the use of wooden utensils was less systematic and many dairies used only plastic and metal equipment.

**Curd stretching**

To impart the typical stringy characteristic to Caciocavallo, the ripened curd is stretched (*filatura*) in hot (85–95 °C) liquid, mainly water but also whey (in six cases) or deproteinised whey (*scotta*) (3). Albeit a slow, laborious process, stretching was always performed by hand. Prior to actual stretching, an artisanal stretchability test (*prova di filatura*) was performed to check the ability of curd for texturing. For this purpose, a small piece of curd is placed in hot liquid (water, whey or *scotta*) and stretched until a continuous length of rope is obtained; as an empirical criterion, about 10 g of curd should form a 1-m-long string. In addition to the length, the cheesemaker also evaluated the 'veil' (*velo*), that is the ability of the rope to extend in width. None of the surveyed dairies systematically checked curd pH before stretching. Due to the artisanal procedure, the duration of stretching was empirically decided *ad hoc* by the cheesemaker and ranged from 5 to 10 min, more than twice the time required for manual stretching for Mozzarella production, the curd being harder and poorer in whey.

**Salting**

Salting in brine after final curd moulding concluded the cheesemaking process of all Caciocavallo varieties. Brine salting was always performed in a single step, except for *C. Irpino di Grotta*, in which the curd was salted in two stages by using different brine solutions and salting times. The salting procedures varied widely both in terms of brine concentration and dipping time (Table 1).

**Ripening conditions and smoking**

Occasionally, Caciocavallo may be consumed fresh (<1 month after production), as is the case of *C. di Ciminà*, which has a typical small size (1.0–1.5 kg), such that a longer ripening time would make it too dry and hard. For the other varieties, the most frequent ripening periods ranged from two to nine months. Within the same Caciocavallo variety, different kinds of ripening environment were documented (e.g. cellars, rooms kept at constant temperature and humidity, unconditioned rooms). Six varieties were ripened in natural caves, and four may be smoked.

## DISCUSSION

While Russian and Balkan Caciocavallo cheeses are typically made from ewes' and goats' milk, or their mixture with cows' milk (Carić 1999), almost all the Italian varieties were produced from cows' milk, except the two from buffalos' milk, and *C. di Ciminà*, for which a small percentage of goats' milk was used. Chemical composition and native microbiota of milk vary from species to species, thus modifying physico-chemical, microbiological and sensory characteristics of the cheeses (Farkye 2004). As a consequence, compared to cheese made using cows' milk, Caciocavallo from buffalos' milk is whiter, due to the lack of beta carotene, and presents a higher fat content (Bergamo *et al.* 2003). According to the study of Niro *et al.* (2014), addition of ewes' (18%) or goats' (35%) milk in making Caciocavallo modifies the microbiological profile (due to the different native microbiota), the chemical composition (higher fat content in the presence of ewes' milk), lipolysis and proteolysis during ripening (due to the different casein profile and triglyceride composition of goats' milk). As a result, the cheeses produced using goats' and ewes' milk present a less sweet taste and lower elasticity, adhesiveness and humidity compared to the cheese produced from cows' milk alone. In the past, traditional Caciocavallo cheeses were produced by using milk from native Italian cattle (e.g. Cinisara, Modicana, Podolian) which have now been replaced to a greater or lesser extent by specialised dairy breeds mainly due to a generalised tendency towards agriculture intensification. Following this trend, it is hardly surprising that the vast majority of Caciocavallo varieties were found to be produced from the most productive breeds in the Italian livestock scenario. Milk from the Brown breed has higher fat and total protein content and better cheese yield than Holstein milk (Perna *et al.* 2014). Although such beneficial features might be a useful tool to differentiate/improve Caciocavallo characteristics, only one dairy farm only used Brown milk. In this regard, the four *Podolian C.* varieties are among the best-known and most acclaimed due to the use of a specific milk which has good cheesemaking properties and excellent organoleptic qualities, related to pasture feeding besides genetic factors (Cosentino *et al.* 2018). Compared to dry diets, pasture and fresh forage are able to convey several aromatic and functional compounds in milk that result in beneficial attributes of dairy products (i.e. healthier fatty acid composition), as well as in modified cheese sensory properties in terms of a yellower colour, less firm texture, stronger and less piquant taste, less sour and less fruity flavour (Carpino *et al.* 2004; Avondo *et al.* 2013; Bonanno *et al.* 2013; Esposito *et al.* 2014; Uzun *et al.* 2018).

The presence of the stretching phase carried out at high temperature makes it possible to produce Caciocavallo by using raw milk (Carić 1999). Heat treatment of milk may have negative (longer coagulation time, weak curd structure) or positive impacts (improvement of cheese yield) on the cheesemaking process (Singh and Waungana 2001). The changes in structure of peptides due to the heating process can also affect cheese proteolysis during ripening, and differences in texture and flavour profiles may result (Benfeldt and Sørensen 2001). However, the most important effect of heat treatment is a smell and taste levelling besides a loss of typicality due to the alteration in the raw milk microbiology profile (Albenzio *et al.* 2001), and a modification in the activity of many indigenous milk enzymes, such as the plasmin/plasminogen complex, lipases or alkaline phosphatase (Grappin and Beuvier 1997).

With the exception of artisanal kid rennet usage in the *C. of Cervati caves and Pertosa,* no other indications on rennet production were found (e.g. origin of calves from which rennet is obtained, as is prescribed for the cheesemaking procedure of *Pecorino Romano* PDO). The rennet was used in liquid or paste form, but little is known about the influence of its physical form on cheese sensory attributes. Along with the starter and nonstarter microbiota, rennet is one of the main proteolytic agents during ripening, responsible for hydrolysis of casein fractions (Farkye 2004; Jacob *et al.* 2011). The lipolytic enzymes exclusively present in kid and lamb rennet hydrolyse milk fat triglycerides releasing free fatty acids, but also originate precursors for a number of other compounds, mainly ketones, aldehydes and esters (Urbach 1997; Addis *et al.* 2008). As a result, the type of rennet can significantly modify cheese flavour, taste and texture (Irigoyen *et al.* 2002; Moschopoulou 2011), and kid or lamb rennet is employed to obtain Caciocavallo cheeses with a sharper taste, while calf rennet gives them a sweeter taste.

Curd stretching is the most characteristic phase of Caciocavallo manufacture that can be performed when curd pH falls as a result of fermentation of lactose to lactic acid through lactic acid bacteria (LAB). Curd acidification can take place under whey/*scotta* or on a metallic or wooden surface. To the best of our knowledge, no studies are available on the effects of these different procedures on *Pasta Filata* cheese sensory characteristics, and investigation is required to shed light on this issue. Some Caciocavallo-making processes rely on the indigenous LAB of raw milk alone to drive acidification but, in many cases, natural starter cultures are added to the milk. The various kinds of natural culture (i.e. milk cultures, natural whey cultures and deproteinised whey cultures) present different LAB composition in relation to the different medium and the techniques used for their reproduction (Parente *et al.* 2017). Hence, the use of one or other of them can influence the characteristics of the final product since natural starter microbiota can also drive ripening processes and help to develop the sensory characteristics of the cheese being made (Giello *et al.* 2017; Guarrasi *et al.* 2017). Moreover, the use of natural cultures denotes *per se* a certain degree of diversity of cheese produced also within the same cheesemaking procedure. Indeed, the thermophile LAB association of natural starters is selected only by the environmental conditions, such that composition and performance of the cultures may vary seasonally and from dairy to dairy (Parente *et al.* 2017).

Although both the US and EU food authorities indicate wood as a porous material that can adsorb bacteria and thus may contaminate food products, Regulation EC 2005 allows its use for traditional foods. Wooden equipment used during processing and the dairy environment are two main sources of LAB microbiota especially when starter cultures are not added to raw milk (Beresford *et al.* 2001). The use of wooden vats in manufacturing *C. palermitano* strongly modified its microbiological profile (Settanni *et al.* 2012; Di Grigoli *et al.* 2015), also contributing to stability of the final product due to the presence in vat biofilm of LAB-producing bacteriocin-like inhibitory substances (Scatassa *et al.* 2015).

The stretching process allows a uniform orientation of the para-caseins that form a characteristic laminar compact texture in which fat globules and moisture are entrapped. Curd stretching may be carried out by means of hot water, whey or *scotta*. Again, the action of whey LAB microbiota can contribute to the ripening process, thereby affecting cheese sensory attributes. Moreover, incorporation of whey instead of water in curd can also convey whey/milk flavour to cheese (Cocconcelli *et al.* 1997; Beresford *et al.* 2001). The vast majority of studies on the physico-chemical changes occurring during stretching and the factors influencing them have been carried out on Mozzarella, since this fresh semi-soft Pasta Filata cheese is currently the world's most produced cheese due to its use as a pizza ingredient (Jana and Mandal 2011). The capacity of curd to plasticise in hot liquid is determined chiefly by the amount of calcium phosphate associated to casein which, in turn, is governed by pH (Lucey and Fox, 1993). If the pH is too high, the curd is tough and can easily fracture during stretching, whereas if the pH is too low, it is excessively soft and can collapse during shaping. As reviewed by Kindstedt *et al.* (2004), due to variations in terms of conditions of acidification, added cultures, composition, degree of ripening and temperature, the ability of curd to be stretched like a long fine piece of rope '*can be achieved over a broad range of combinations of total calcium content and pH*'. Hence in the traditional artisanal manufacture of Caciocavallo, the stretchability test is still the yardstick for establishing the degree of maturation, and none of the dairies systematically checked curd pH.

The actual stretching temperature is determined by the temperature and mass of the liquid used combined with the temperature and mass of the curd processed, and can vary in relation to the cheesemaking procedure. It has been empirically demonstrated (Addeo *et al.* 1996) that in Mozzarella production, the high whey content of curd allows both plasticisation of curd already at 58 °C and a broad optimal range of temperature for texturing (58–83 °C). By contrast, the minor content of whey left in curd during production of Caciocavallo causes a high minimum melting temperature (61 °C) and a narrow temperature range for texturing (70–77 °C). The temperature of curd during stretching must not be far from the values previously indicated since it may negatively impact, if higher, upon the properties of cheese such as shredding and melting or, if lower, cheese yield due to fat loss (Kindstedt 2007).

The salting procedures were extremely variable, but were always performed by brining unlike Russian and Balkan *kashkaval* cheeses traditionally dry salted during the first 2-3 weeks of ripening (Kindstedt *et al.* 2004). As a general consideration, shorter salting time corresponded to higher salt concentration although, due to the large variability in dipping time and concentration, it might be easily expected that the magnitude of salt uptake differed among the different varieties. Salt in cheese primarily acts as a preservative, but it contributes directly to cheese flavour since it is a major determinant in cheese water activity, and it thereby exerts microbial growth control, enzyme activity, biochemical change during cheese ripening and organoleptic profile development (Farkye 2004; Guinee 2004). Therefore, the magnitude of salt uptake in the cheese matrix from brine can affect composition, physical and rheological properties and, as a consequence, sensory quality and consumer acceptance of ripened cheese (Fucà *et al.* 2012). High variability of salt concentrations of *Monti Dauni Meridionali C.* (from 8.57 and 15.29%) was found in relation to different brine concentrations and time of dipping adopted by dairies. Anyhow, a moderate concentration of brine for cheese salting has a positive influence on consumer preferences (Santillo *et al.* 2012).

Although many kinds of ripening environments were found within the same cheese type, ripening in caves was specific to only five varieties. The higher relative humidity and the lower temperature of natural caves can strongly influence the sensory attributes of cheeses. In particular, hardness, friability and flavour intensity are higher for cheeses ripened in caves, which are thus perceived as 'more ripened' (Torracca *et al.* 2016).

Although smoking is one of the oldest methods of preservation, it has changed its main objective and today is used to modify cheese sensory properties (Aydinol and Ozcan 2013). More than 300 compounds, such as acids, alcohols, esters, hydrocarbons, aldehydes, ketones, furan and pyran derivatives, terpenes and sesquiterpenes, have been identified in smoke, but only a very small number have been recovered in smoked food products (Guillén and Sopelana 2004). Smoking adds desired sensory properties to cheeses in terms of colour (from golden yellow to dark brown), flavour (from very light to a heavy smoky taste) and texture (producing a drier texture) (Elortondo *et al.* 2002).

## CONCLUSIONS

This study surveyed the manufacturing processes of the traditional Italian Caciocavallo cheeses labelled as TFP. Milk and rennet types, curd acidification and salting procedures, ripening conditions and smoking treatments were identified as the main manufacturing variations able to differentiate the organoleptic characteristics of the cheeses. Nevertheless, it was not possible to clearly discriminate among the many varieties since, apart from milk species, the manufacturing variants able to influence sensory properties were found across more than one variety. Moreover, the results of the survey and the literature analysis suggest that factors common to many procedures, such as use of raw milk, natural starters and wooden utensils as well as the differences in ripening conditions, can lead to more variability within the same cheese type than between them. Overall, this survey, albeit qualitative in nature and carried out on a specific cheese, may provide consumers with useful information regarding perceivable effects of the manufacturing variants examined. For dairy operators and cheesemakers, it may serve as a support in certain decisions regarding communication about their product characteristics. Finally, the survey highlighted the scarcity of detailed reports on the role of particular acidification procedures and on the physical form of rennet.

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## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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