

The Science behind Traditional Products: The Case of Portuguese Cheeses

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Abstract—Portugal is situated in the Iberian Peninsula, having climacteric influences of the Atlantic Ocean together with the Mediterranean Sea, which, allied to the landscape and fertile soil results in good pastures that potentiate the animal production. Hence, Portugal is very rich in what concerns traditional cheeses, made with cow, goat, sheep or mixture milks, and which are characterized by very particular tastes, colours and consistencies, besides being also different in terms of chemical composition. The number of Portuguese traditional cheeses is very high, although only a part of them have already been registered under the European Union designations for protection of origin. These have different processing technologies and are characterized by singular aspects that differentiate among them. In this way, they can be classified in terms of the type of milk used for its production, or in terms of the fat content, or even the type and intensity of ripening or finally according to the consistency of the paste. Traditional cheeses are very important in social terms, because they accumulate the history of a people and a country, besides providing a means of income for the rural populations that live from the pastures and the cheese manufacture. Cheeses comprise nutritional properties for being a good source of proteins, lipids, minerals (such as calcium, phosphorus and zinc) and vitamins (like vitamin A, riboflavin, folic acid and vitamin B12). Nevertheless, when it comes to traditional cheeses, they have to be consumed with moderation due to the high fat content present because they are usually made with whole milk.

Index Terms—traditional Cheese, health, Protected Designation of Origin (PDO), authenticity

I. INTRODUCTION

Cheese is, presumably, the most ancient processed food of mankind. It is a product made from the coagulation of milk, and the art of its manufacture begun in a remote past, about 12 thousand years B.C. The art of making cheese by hand was passed from mother to daughter in the families of the shepherds, always paying attention to the smallest details like the temperature of the hands, the time of curdling, the turning as well as the pastures and type of feed that conditioned the characteristics of the final cheese. Nevertheless, in ancient times, the cheese production was much more simple than today, and the first cheeses were obtained only from the milk coagulation without the addition of

any other components, like for example salt. From the Middle Ages, the manufacture of more refined cheeses would be restricted to Catholic monasteries, with new recipes developed by their monks. The technique of cheese production has modernized over time. Some fungi spores are used in some cheeses and added to milk. The production technology of cheese, so much appreciated in old times as today, is based on three fundamental discoveries: 1) the discovery of milk; 2) the discovery of curdle technology and whey separation; and 3) discovery of rennet (animal or vegetable) [1], [2].

The Egyptians are among the first people who tended cattle and had, in milk and cheese, an important source of their food. This was possible because the fertile valley of the Nile had rich pastures that were full of cattle. The cattle were so important for the Egyptians that they even included cow horns on the head of their beloved goddess Hathor. Meanwhile, evidence of cheeses made from cow's milk, goat's milk and sheep's milk were encountered in numerous Egyptian tombs. Bible passages report cheese as one of the foods of those times. In Europe, the Greeks were the first to adopt it in their menus, made exclusively with milk of goats and of sheep, animals that they created. However, the Romans were responsible for the greater spread of cheeses around Europe and the rest of the world. In the expansion of their Empire they brought various types of cheese from different places to Rome. They raised the level of the cheese, transforming it from simple food to an indispensable delicacy in the meals of the nobles and in great imperial banquets. The Romans appreciated the cheese, of which they made many varieties and whose virtues they knew, since they used it in the feeding of soldiers and athletes [2], [3].

With a deep relationship with mythology and deities, milk and cheese were more widespread in ancient Sumer, through the Babylonian and Hebrew civilizations, and ending in Ancient Greek and Roman civilizations. However, it was only in the Middle Ages the cheeses reached one of the highest points when it comes to hygiene. Certain religious orders have gained a reputation because of the quality of their cheeses, due to the strict rules of hygiene in their manufacture [2].

With the advent of fairs and markets in the fourteenth and fifteenth centuries, some dairies from remote regions became more targeted. In the nineteenth century occurred the great boom in the consumption of cheese, and as a

consequence its production turned from artisanal to the industrial scale. It was also then that the pasteurization process was introduced in the manufacture of cheese [4], [5].

Over time, cheese has evolved to the ones we know today, and it has become a consumer product of choice with connoisseurs scattered all over the world. This food is nothing more than a derivative of concentrated milk through coagulation and elimination of the liquid part (serum). These processes of coagulation and elimination of serum thus become the stages that characterize the production of all varieties of cheese.

II. CHEESE TECHNOLOGY

Cheeses are dairy products present in almost every county in the world, being much varied in terms of flavour, shape, texture, colour, chemical and biological composition or nutritional value [6].

The natural bacteria present in milk use the lactose, a sugar present in milk, as a source of energy to produce lactic acid. Hence, they are called lactic bacteria and they grow and reproduce well at room temperature. After a specific amount of lactic acid is present in the milk, its pH becomes lower, and the casein, which is the main protein in milk, coagulates at its isoelectric point (pH = 4.6), originating a gel-like structure that retains the fat and aqueous phase [6], [7].

A relevant number of cheese varieties were obtained from fortuity causes due to certain local circumstances, like milk composition, endogenous microbiota, species and animal breed and feed, or even due to a sole event that occurred during the production or storage processes, like for example the mould growth (Fig. 1). Apparently, the accidents that caused these changes in the quality of the cheese for the better were then incorporated into the manufacturing protocol and have experienced evolutions over the years [6], [8].



Figure 1. Some examples of cheeses with moulds.

Milk originated from different animals can be used for the production of cheese, such as for example cow, sheep, goat, mule or buffalo or even, like in many cases, mixtures of different milks. The milk produced on a farm is a bulk mixture of the individual contributions of all the animals' milking, and its composition is intimately related to the animal breed, its feed, the lactation phase as well as its global health status. The characteristics of the milk, including its chemical composition and nutritional value, rheological properties and microbiology (types and amounts of microorganisms present), will importantly impart the ultimate properties of the obtained cheese. Besides, the activity of milk coagulating enzymes has a

pivotal part in the degradation of the milk protein (casein) to smaller peptides and free amino acids, which in turn lead to the development of particular sensory characteristics in the cheese owing to the presence of volatile compounds like alcohols, aldehydes, acids, and esters that originate from the degradation of those amino acids [9]–[12].

While in the industrial cheese production the milk used is usually pasteurized, in the case of artisanal cheese production the milk is used raw, thus giving place to distinctive smells, textures and tastes that the native microbiota of raw milk provide. Nevertheless, a lot of other factors, like the production environment, climate or type of cattle feed, also meaningfully influence the unique characteristics of the final cheese [7], [13].

The cheese manufacture process is essentially a concentration of milk in which part of the solid components (protein and fat) are concentrated in the curd while proteins of the serum, lactose and soluble solids (minerals and vitamins) are removed in the whey (Figure 2), which is the aqueous portion that splits during the process, and which retains about 55% of milk nutrients. Around 85 to 90% (v/v) of the milk used in the manufacture of cheese is turned into whey and approximately 75% of milk proteins are retained in cheeses obtained by enzymatic coagulation [6], [10].

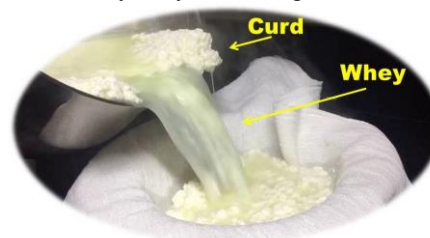


Figure 2. Curd and whey phases in the cheese manufacture process.

Cheeses produced by acid coagulation or hot protein coagulation processes are normally consumed fresh. On the other hand, the great majority of the cheeses coagulated by the action of enzymes, with the use of curds or coagulants, are matured or cured for a period of time ranging from three weeks up to more than two years [6], [13].



Figure 3. Cheese ripening.

Ripening is a phase where the cheese is maintained under determined controlled conditions of temperature

and relative humidity (Fig. 3), and during which many microbiological, biochemical, physical and chemical modifications take place. This operation allows obtaining products with certain appreciated characteristics of flavour, aroma and texture allied to good preservation capacity. The sensory characteristics of cheese are modified by the extent of proteolysis and lipolysis during manufacturing and ripening, in particular the level of degradation of casein into peptides and amino acids [6], [9], [12].

The use of salt in cheese manufacture goes far beyond the enhancement of taste since it plays a number of important roles, like: promoting surface dehydration thus helping in the formation of cheese; modifying the osmotic pressure resulting in mass syneresis; controlling the growth and microbial activity; helping the biochemical control of maturation; and finally producing physical changes in cheese proteins that influence its texture [14], [15].

III. SOME OF THE MOST PROMINENT PORTUGUESE TRADITIONAL CHEESES

In Portugal many cheeses are produced and commercialized, some of them being very ancient artisanal products and others more industrialized and using more recent technology. From the near 100 traditional cheeses, some, due to their importance and regional or national relevance, have gone through certification processes being officially recognized according to the European Commission certification schemes, and are now products with PDO (Protected designation of origin). From those, some will be presented along this work.

A. Cheese from Serra da Estrela

Serra da Estrela Cheese is obtained from raw milk, from sheep of two specific Portuguese breeds: *Bordaleira da Serra da Estrela* or *Churra Mondegueira* (Fig. 4). It is a cured cheese, which can have semi-soft buttery paste and yellowish-white colour in case of the *Serra da Estrela* Cheese, or semi-hard to extra-hard paste of brown-orange colour in the case of *Serra da Estrela Old Cheese* [16].



Figure 4. Sheep from breeds *Bordaleira da Serra da Estrela* (Top) and *Churra Mondegueira* (Bottom).

The *Serra da Estrela* Cheese is the oldest of all Portuguese cheeses, being internationally recognized for its much appreciated organoleptic characteristics. It reached Portugal during the Roman occupation and during the Middle Ages it was mentioned in the work of the poet Gil Vicente. In 1287, King *Dom Dinis* created the first cheese shop in the county of *Celorico da Beira*, in the *Serra da Estrela* region. Because this cheese represented a most valued food source, it was used by the great explorers during their travels in the discoveries that parted from the Portuguese coast through the Atlantic Ocean and to discover the *New World* (American continent) and *Indias* (Asia). From 1885 it started to be commercialized in the major Portuguese cities of Lisbon and Porto, increasing its fame [1], [3].

The process of obtaining the *Serra da Estrela* cheese begins with the manual milking of the sheep, followed by its filtration through white cloths. This is then heated to a temperature of about 28-32 °C and salted, and then added vegetable rennet for coagulation. The coagulant used is the wild thistle flower (*Cynara cardunculus*), previously dried and grounded. After 45 to 60 minutes, the curd is manually cut and a new filtration is done to remove the remaining serum. After the steps of molding, pressing and new surface salting, the cheese is ready for the following phase, the maturation or ripening. This occurs in two stages: the first occurs up to 15-20 days, at temperatures of 6 to 12 °C and relative humidity of 85 to 90%, and it involves daily turns and washings; the second phase lasts up to 45 days at 6-14 °C and relative humidity of 90-95%, and here the turns and washings are made sporadically, depending on the aspect of the crust. For the manufacture of *Serra da Estrela Old Cheese*, the same temperatures and relative humidity are used, varying only the minimum maturation time, which is 120 days [17]–[21].

The *Serra da Estrela* Cheese has a smooth, clean and slightly acidic flavour and aroma, with a very soft core, with a spreadable paste, which constitutes one of its unique and much appreciated particularities (Fig. 5). The *Serra da Estrela Old Cheese* has a pleasant, persistent, clean aroma and flavour, being slightly strong, spicy and salty. The texture is also somewhat soft, although firmer and not spreadable, with some typical holes inside (Fig. 6) [16], [22].



Figure 5. *Serra da Estrela* Cheese.



Figure 6. *Serra da Estrela Old Cheese*.

Table I shows the chemical [22] and microbial composition of Serra da Estrela Cheese [23], [24].

TABLE I. CHEMICAL AND MICROBIAL COMPOSITION OF SERRA DA ESTRELA CHEESE

Component	Amount
Moisture (g/100 g)	50
Fat (g/100 g dry solids)	49
Protein (g/100 g dry solids)	38
Ash (g/100 g dry solids)	8
NaCl (g/100 g dry solids)	5
Enterobacteriaceae (coliforms) (CFU/g)	10 ⁵
Lactic acid bacteria (LAB) (CFU/g)	10 ⁷
Yeasts (CFU/g)	3x10 ⁰ –1x10 ⁷
Staphylococci (CFU/g)	3.6x10 ² –2.5x10 ⁸

B. Cheese from Castelo Branco

The cheese from *Castelo Branco* is a matured cheese produced from raw sheep's milk, and is characterized by a semi-hard or semi-soft core with a yellowish hue (Figure 7). Like in the Serra da Estrela cheese also in this case the rennet used is the thistle flower, and the maturation is done under controlled conditions (8 to 14 °C and 80-90% relative humidity) for at least 45 days. In the case of cured cheese with hard to extra-hard cheese paste, designated as *Old Castelo Branco Cheese*, the maturation process lasts for at least 90 days, and the final product is characterized by an intense and slightly spicy flavour and aroma. The surface can be covered with red pepper paste or aluminium paper (Fig. 8) [16].



Figure 7. Castelo Branco Cheese.



Figure 8. Castelo Branco Old Cheese.

Table II shows the chemical [22] and microbial composition of Castelo Branco Cheese, at 40 days of maturation [23], [25], [26].

TABLE II. CHEMICAL AND MICROBIAL COMPOSITION OF CASTELO BRANCO CHEESE

Component	Amount
Moisture (g/100 g)	39.4
Fat (g/100 g dry solids)	54.0
Protein (g/100 g dry solids)	36.5
NaCl (g/100 g dry solids)	6.2
pH	6.3
Enterobacteriaceae (coliforms) (CFU/g)	10 ² –10 ⁵

C. Cheese from Nisa

The cheese from Nisa is obtained from raw sheep's milk, original from a regional breed (*Merina Branca*) (Fig. 9). It is a cured cheese, with a semi-hard paste and a yellowish white colour, whose maturation involves 2 stages. The first lasts about 15–18 days and the cheese is kept at a temperature between 8 and 10 °C and a relative humidity of 80 to 90%. The second stage lasts between 30 to 40 days and in this the temperature is set to 10–14 °C and relative humidity to 85–90% [16].



Figure 9. Sheep from breed Merina Branca.

This traditional cheese has long been known in the central region of Alto Alentejo, being mentioned by António Maria Horta Camões in 1901. It has been part of the daily life of the people in the city of Portalegre and its surroundings for several generations, being the main source of protein for the local people, who had, in general, a very poor diet [16].

It can be presented in the variant of a small cheese, with a weight of 200 to 400 g, or in the original size, with a weight of 800 to 1300 g (Fig. 10). It has a slightly acidic flavour and intense aroma.



Figure 10. Cheese from Nisa.

Table III shows the chemical composition of Nisa Cheese, at 45 days of maturation [16], [22].

TABLE III. CHEMICAL AND MICROBIAL COMPOSITION OF NISA CHEESE

Component	Amount
Moisture (g/100 g)	40.6
Fat (g/100 g dry solids)	53.5
Protein (g/100 g dry solids)	41.8
NaCl (g/100 g dry solids)	4.2
pH	5.2

D. Cheese from Rabaçal

Cheese from Rabaçal is a cured cheese of artisanal production from a mixture of sheep and goat's milk coagulated by a rennet from animal origin. It is a semi-

hard to hard paste cheese, with a clear colour and just a few small and irregular eyes [16]. The origins of Rabaçal Cheese are ancient, being mentioned in written documents far back in 1139, and its quality and reputation were referred by numerous authors, among them Eça de Queirós [16].

The distinctive flavour of this cheese is mostly influenced by a spontaneous thyme (*Chenopodium ambrosioides*), which grows abundantly in the area where the sheep and goats that supply the milk for the production of this cheese eat [16].

The colour is yellowish and the odour is much appreciated. There are those who prefer it fresh, but it becomes very good after a cure of three to four weeks. It has an intense and clean flavour and a semi-hard paste (Fig. 11) [27].



Figure 11. Cheese from Rabaçal.

Table IV shows the chemical and microbial composition of Cheese from Rabaçal, at 28 days of maturation [16], [23], [28].

TABLE IV. CHEMICAL AND MICROBIAL COMPOSITION OF CHEESE FROM RABAÇAL

Component	Amount
Moisture (g/100 g)	35.8
Fat (g/100 g dry solids)	52.5
Protein (g/100 g dry solids)	39.9
Ash (g/100 g dry solids)	5.5
pH	4.8
Water activity	0.925
Enterobacteriaceae (coliforms) (CFU/g)	10 ⁴ –10 ⁵

E. Cheese from Azeitão

The cheese from Azeitão is a cured, semi-soft and buttery cheese, white or slightly yellow in colour, being produced after raw sheep's milk (Fig. 12). This cheese has a spicy, acidic and salty taste, being its organoleptic characteristics derived from the edaphoclimatic conditions of the region, which influence the quality of the pastures. On the other hand, they are influenced by the use of thistle flower as coagulant [16].



Figure 12. Cheese from Azeitão.

The cheese of Azeitão began to be produced in the 19th century, by Gaspar Henriques de Paiva, who took the initiative to create sheep from his region in Azeitão. As a consequence, he started to elaborate cheeses with similar characteristics to those of the Serra da Estrela Cheese, but soon realized that this cheese had distinct, highly appreciated, easily recognized and rewarding characteristics [16]. The maturation process lasts for 20 days at a temperature of 10-12 °C and relative humidity of 85 a 90% [16].

Table V shows the chemical [22], [29]. and microbial composition of Cheese from Azeitão [23], [30] at 20 days of maturation.

TABLE V. CHEMICAL AND MICROBIAL COMPOSITION OF CHEESE FROM AZEITÃO

Component	Amount
Moisture (g/100 g)	47.0
Fat (g/100 g dry solids)	46.9
Protein (g/100 g dry solids)	41.1
Ash (g/100 g dry solids)	7.3
NaCl (g/100 g dry solids)	4.0
pH	5.9
Enterobacteriaceae (coliforms) (CFU/g)	10 ⁶ –10 ⁷
Lactic acid bacteria (LAB) (CFU/g)	10 ⁸
Yeasts (CFU/g)	10 ⁶

F. Cheese from São Jorge

Cheese from São Jorge is obtained from raw milk of cows that pasture freely in the Azorean island of São Jorge (Fig. 13). It is a cured cheese, with hard or semi-hard paste and yellowish colour (Fig. 14). The production of the São Jorge cheese dates back to the time of the discovery of that island, in the mid-fifteenth century. Its manufacture started in the Flemish community, experienced producers of food products such as meat, milk and dairy products. They found on the island a climate similar to their own origins, ideal for the production of this particular cheese, that retained its distinctive characteristics over the years [16], [31].



Figure 13. Cows in the Pastures of the Azorean islands.



Figure 14. Cheese from São Jorge.

At least 60 days of maturation are necessary for the cure of this cheese, at a controlled temperature of 12 to 14 °C and relative humidity of 80 to 85% [16], [31].

The distinctive characteristics of São Jorge cheese are due, on the one hand, to the soil-climatic conditions of that region, which potentiate very rich pastures. On the other hand, its manufacture process practically unchanged over the 500 years, also promotes the uniqueness of the product. It possesses a slightly strong, clean and slightly spicy flavour and aroma [16], [31].

IV. FINAL CONSIDERATIONS

Portugal has a very rich tradition in cheese making, being this activity a support for families from many centuries ago. Tradition related to milk products and cheeses in particular has led to the application for the European designation of PDO in many of those products, so that presently a wide range of PDO cheeses, both cured or fresh as well as creamy cheeses, can be found in Portugal.

These products greatly contribute for the economical sustainability of the populations and at the same time preserve their uniqueness and contribute for the dissemination of the people's identity. These cheeses are extremely popular in Portugal but some of them have expanded into international trade and are now appreciated in many countries around the world.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Raquel Guiné wrote the article and supervised the work, Sofia Florença helped in bibliographic search and revised the paper.

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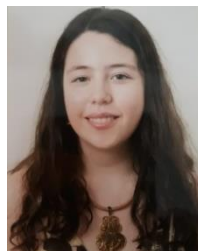
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Scientific achievements: Author/co-author of about 20 books, 50 chapters, 200 research papers and 250 conference proceedings. Has authored about 160 oral communications and 120 posters presented at scientific conferences. [*Scopus ID: 6603138390; H-index 17, 856 citations*)] [*Research Gate Profile: https://www.researchgate.net/profile/Raquel_Guine*]

Global leader of a team of 76 researchers working under the International Project "EATMOT" involving 18 countries: Argentina, Brazil, Croatia, Cyprus, Egypt, Greece, Hungary, Italy, Latvia, Lithuania, Macedonia, Netherlands, Poland, Portugal, Serbia, Slovenia, Romania and United States of America [*website of the project: <https://raquelguine.wixsite.com/eatmot>*]

Large experience in supervision of Master thesis (30 finished, 4 in progress).

Organization of 20 conferences/meetings and Scientific Board for 34 conferences. [*More details at webpage: raquelguine@esav.ipv.pt*]



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She has already participated in research work, writing some articles for publication and chapters, as well as participation in conferences as author or co-author of oral or poster communications.

She has won a prize as the second place for best e-poster, at the 1st International Meeting on Innovation & Development in the Food

Sector, that took place in Viseu-Portugal in June 2018.

Is author/co-author of 1 book chapter, 2 conference proceedings, 2 oral communications and 2 posters presented at scientific conferences.