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REVIEW ARTICLE

A synoptic overview of durum wheat production in the Mediterranean region and processing following the European Union requirements

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Abstract

Cereals are a group of cultivated plants belonging to the grass family that produces grains rich in starch with specific dough properties. These grains are easily harvested, due to the structure and, if under appropriate storage, the mature seeds preserve its qualities and nutritional value for a long time. The gradual shift to a steady-production based agriculture has been the main driving force behind the domestication of wheat, namely durum wheat. The world durum wheat steady-production, which prevails in the Mediterranean region, is mostly used in the production of pasta, yet the quality definition requires the control of fungal phytopathogens, industrial unit operations and additives applications. This paper reviews some aspects of durum wheat production and industrial processing, further considering phytopathogenic infections and the application of food additives.

Key words: Durum wheat production, Food additives, Industrial processing of pasta, Phytopathogens

1. Origin, domestication and evolution of wheat

The earliest signs of crop domestication appeared 10,000-12,000 years ago in the Fertile Crescent of the Near East, in the Central America, and in the southern of China. In the Fertile Crescent of the Near East, near of Tigris and Euphrates rivers, wheat domestication was founded on crop reliability, yield and suitability for storage (Lev-Yadun et al., 2000). Eventually, man collected and possibly cultivated wild forms of wheat, selecting for nonshattering, free-threshing, non-brittle rachis and hull-less spike characteristics and for higher yield. Also, in all cereals, the easiness of harvest, yield and suitability for short and long-term storage have been critical for domestication.

The evolution and domestication of various forms of cultivated wheat (diploid – *Triticum monococcum*, tetraploid – *Triticum turgidum* and hexaploid –*Triticum aestivum*) within the entire *Triticeae* tribe included early widespread intragenome and intergenome hybridization, followed by introgression, gene flow, gene fixation and rapid diversification within and among the ancestral diploid and polyploid species (Kellogg et al., 1996).

Wheat cultivation spread in all directions, but the Mediterranean basin played an important role in its differentiation, in particular of durum wheat (Núñez, 2003). In the Iberian Peninsula, the cultivation of wheat was found 4,000 years ago (López Bellido, 1991).

Modern wheat cultivars belong primarily to two polyploid species, namely hexaploid bread wheat – *Triticum aestivum* L. (2n=6x=42 chromosomes) and tetraploid hard or durum-type wheat – *Triticum turgidum* L. (Thell.) (2n=4x=28 chromosomes).

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2. Durum wheat production and consumption in the world

Durum wheat production reaches around 30 million tons in about 16 million hectares. Durum wheat productions areas are concentrated in the Middle East, North Africa, the former USSR, the North American Great Plains, India and Mediterranean Europe. The Mediterranean region produces about 60% of world durum wheat production (Morancho, 2000), being the European Union (Italy, Spain, France and Greece) the leading global producer. Despite these numbers, the production of durum wheat represents only 8% of world production of wheat (Manzano, 2007).

In general durum wheat is colder sensitive than bread wheat, but is better adapted to high temperatures and to semiarid climates, being insolation important to this crop. Such tolerance to higher temperatures seems to be related to a higher tolerance of the photosynthetic metabolism (Dias et al., 2011), probably related to a higher thermal stability of cellular membranes (Dias et al., 2010). Favourable zones for durum wheat maturation require an average of more than 250 hours of sun during the harvest preceding month. Eventually, these conditions prompt the traditional implementation of this crop in the semi-arid zones of the Mediterranean basin (Royo, 1998).

In spite of its relatively low area of production, durum wheat is an economically important crop due to its unique characteristics and end products. It is generally considered the hardiest of all wheat. Durum kernels are usually large, golden amber, and translucent. These characteristics, as well as its protein content and gluten strength, make it suitable for manufacturing diverse food products, namely pasta that is the most common durum wheat end product consumed in Europe, North America and in the former USSR countries. Indeed, Italy tops the world rankings from consumption of dry pasta per capita/year with a value of 28 kg/inhabitant/year, followed by USA, Chile, Greece, Venezuela, Tunisia, Switzerland, Peru and, finally, France, Russia and Argentina with an average consumption of 9 kg per inhabitant/year (Roncallo et al., 2009). Additionally, couscous, are also made from durum wheat semolina, being largely consumed in North Africa (Algeria, Morocco and Tunisia) and Middle East, whereas flat bread made from durum wheat and bulgur are part of the main diet in Jordan, Lebanon, and Syria (Nachit et al., 1992; Quaglia, 1988; Palumbo et al., 2000).

2.1. Climate, Agronomy and Quality

By its extensive ability to adaptation, wheat is cultivated in a wide variety of climates. The latitude having favourable cultivation area extends between 30º and 60º north and 25° and 40° south, mostly in regions whose precipitation ranges between 300 and 1000 mm annually (González and Rojo, 2005). As wheat was originated in dry climate regions, it became well adapted to the steppes, where it is intensely sown. It can also be produced in areas of relatively cool and humid weather during the growing season, followed by a hot and dry period during grain filling.

In the Mediterranean climate, which prevails in the south/southwest of Europe, North Africa, California, Chile, South Africa and South Australia, the summer is very long, hot and dry and the precipitation is concentrated in autumn and winter. Winter is also often short and mild (Maçãs, 1996). The regions with this type of climate represent 10-15% of the total production of wheat globally (Loss and Siddique, 1994).

The water deficit is one of the main factors limiting durum wheat yield in the Mediterranean region (Bennet et al., 1998). Temperature starts to rise in spring, often sharply which concurs with the cereal water demand. However, rainfall in this season is often relatively low and very irregular, which can also cause water deficit problems, together with high temperature exposure. This stage normally coincides with the emergence, flowering and grain filling, triggering reduction in the number of spikes by plant and in the number of grain per spike and frequently also grain weight reduction (López Bellido, 2009; Maçãs et al., 1999, 2000). Performance is determined by the distribution of total rainfall during crop development (Slafer, 2003; Cossani et al., 2009). Thus, the unpredictability of the Mediterranean climate causes fluctuations in wheat yield and quality, but offers the opportunity for obtaining high-quality durum wheat in terms of the most important parameters required by industry (Table 1).

Table 1. Range values for high quality durum wheat parameters.

Quality parameters	Range values
Protein Content (%)	>13
Yellow Pigment Content (ppm)	>7
Ash Content (%)	< 1,8
Vitreousity (%)	> 75
Wet Gluten Content (%)	> 40
Test Weight (kg/hl)	> 78
Hagberg Index (s)	> 250
SDS Sedimentation Test (mm)	> 50
Moisture Content (%)	< 12

The performance of many quality characteristics depends greatly on environmental conditions, which result in differential expression of grain quality from site to site. In fact, grain protein content, perhaps the most important quality feature for wheat, is known to be influenced by climatic parameters, cultivar, nitrogen fertilizer rate, time of nitrogen application, residual soil nitrogen and available moisture during grain filling (Campbell et al., 1981; Rao et al., 1993; Uhlen et al., 1998; Rharrabti et al., 2001). Vitreousness is mainly affected by nitrogen and water availability, and humid environments reduce the percentage of vitreous grains and increase the incidence of black point (Robinson et al., 1979). Environmental conditions can also influence ash content, which increases under high-transpiration environments (Araus et al., 1998). Thousand-kernel weight and test weight are greatly determined by climatic parameters, particularly high temperature during the grain filling. Gluten strength, can also be reduced in dry and hot environments (Blumenthal et al., 1991; Graybosh et al., 1995; Rharrabti et al., 2003).

2.2. Phytopathogenic fungal infections

Wheat infections caused by phytopathogenic fungal strains able to produce toxic metabolites, such as trichothecenes, zearalenone, aflatoxins, fumonisins and ochratoxin A, sterigmatocystin, T-2 toxin have relevant implications. These toxic compounds are low molecular weight secondary fungal metabolites known as mycotoxins (Prandini et al., 2009). The presence of mycotoxins, exerts a severe adverse effect on human and animal health due to their recognized toxic properties, which depend on the mycotoxin and its dose. It is well known the biological effects in animals, such as liver and kidney toxicity, effects on the immunological and central nervous system among others (Whitlow and Hagler, 2005). On the other hand, the contamination of wheat with mycotoxins has serious economic consequence. The grain quality is compromised not only by deterioration with selective loss of albumin and gluten proteins, but also with important losses in grain yield (Muller et al., 2010). Due to the global importance of wheat in the human diet or animal feed its susceptibility to be contaminated by fungi or/and by their natural toxins is a concerning fact (Table 2). HACCP approach is an important tool in order to quantify hazards and identify critical control points for controlling mycotoxin production and its entry into food chain and also to know the threshold limits for growth (Hope and Magan, 2003).

The capacity of a mycotoxin-producing strain to contaminate the cereal depends on several factors such as genetic, composition of grain, environmental and agricultural management. The different crop management practices, such as crop rotation, tillage and cultivar were pointed out as important abiotic drivers (Muller et al., 2010). For instance, Muthomi et al. (2008) reported that the management strategies for *Fusarium* head blight include crop rotation, seed treatment, planting different cultivars, irrigation and weed control, proper land preparation, timely harvesting, appropriate use of fertilizers and fungicide application (Muthomi et al., 2008).

It is known that the initial infection of a floret follow the spread to the spikelets of the same head. However, there is controversy about the mechanism of nutrition use by these pathogenic fungi. A microscopic study conducted by Brown et al. (2010) reported that *Fusarium graminearum* PH-1 hyphae colonized susceptible wheat ears and spread from spikelet to spikelet, adapting their hyphae to the available intracellular space between host cells, resulting the loss of their entire cellular contents just prior to intracellular colonization. According to these authors the advancing cortex infections progress resulted in the collapse of the non-lignified cell types, the pathogen draw from predominately vertical to lateral growth and accumulated below the surface of the rachis. At this stage the lignified host cell walls became profoundly degraded and hyphae ruptured the epidermis and produced an aerial mycelium (Brown et al., 2010).

There are several fungal strains able to produce natural toxins that are extremely susceptible to environmental factors, such as temperature, relative humidity, insect attack, pests damage, fertilization balance and stress condition (Schmidt-Heydt et al., 2009). The presence of these secondary metabolites has been reported at different stage of the food chain, such as pre-harvest, processing, transportation and finally in the storage, indicating that fungus colonization may occur before or after harvest, depending upon environmental or storage conditions. In the case of ochratoxins, the production and occurrence of this mycotoxin in the cereal grains is deeply dependent on the condition of the grain at harvest, how carefully the grain is dried and the quality of the storage facilities (Duarte et al., 2010). Since chemical composition of seeds involves their moisture content, seeds with high oil content have less moisture than seeds with high protein or starch content. For example, moisture content below 20% prevents ochratoxin A production (Scudamore et al., 1999). Besides that, it has been described that high content of ochratoxin amino acid precursors, such as glutamic acid could be a cofactor for the mycotoxin production (Gonzalez-Osnaya et al., 2007).

Nowadays, it is known more than 300 natural toxins isolated and characterized, aflotoxins and ochratoxins are the most important among them. They represent an important group based on their toxicity and occurrence. Indeed, ochratoxin A represent the most widespread mycotoxin in the wheat (Duarte et al., 2010). The EU regulation established for ochratoxin A values of 5 µg/kg for raw cereal and 3 µg/kg for all products derivated from cereals (CEC, 2006). In the case of aflatoxin B1 and the total of aflatoxins a limit set of 2 µg/kg and 4 µg/kg was established, respectively (UE, 2010). Recently it was found 3.0 µg/kg of ochratoxin in the wheat (Ghali et al., 2008). Moreover, it was reported in Kenya wheat products the presence of more than one of the four mycotoxins analyzed (Muthomi et al., 2008). The co-occurrence of different mycotoxins in the grain can affect both the level of mycotoxin production as well as the toxicology of the contaminated grain resulting in synergetic and additive effects (Muthomi et al., 2008).

According to International Agency of Research of Cancer (IARC, 1993), aflatoxins were considered as a possible human carcinogen. Previous studies showed that these mycotoxins have immunosuppressive, teratogenic and hepatotoxic properties. On the other hand, teratogenic, genotoxic, embryotoxic, immunosuppressive, carcinogenic, neurotoxic and nephrotoxic effects have been described as a consequence of ochratoxin A activity (JECFA, 2001).

Mycotoxins are produced by several fungal strains of *Fusarium* spp., *Aspergillus* spp. and *Penicillium* spp. (Schmidt-Heydt et al., 2008). These three fungal species are filamentous ascomycetes and are the most casual agents of wheat disease. Depending on the fungal species the mycotoxins produced have different toxigenic profiles. It has been reported that each strain shows different behaviors in what concerns to geographical occurrence and ecological niches. For example, in tropical regions *Aspergillus ochraceus* is the main responsible for ochratoxin A production, meanwhile in temperate to cool climatic regions *Penicillium verrucosum* that grows optimally below 30ºC and with water activity (aw) values of 0.80 was described as the principal agent of wheat disease (Zinedine et al., 2006). Indeed, there are several *Aspergillus* species known to be able to produce ochratoxin A, some of them appear in the countries with warm temperatures, while others are found in tropical and sub-tropical ones, showing a clear relation between mycotoxin occurrence and climatic conditions, particularly in what concerns to moisture and temperature (Duarte et al., 2010). These two factors are critical growth parameters. The strains *Aspergillus ochraceus*, *A. westerdijkiae* and *A. steynii* have an optimal temperature of 24-31ºC and aw values of 0.95-0.99. Meanwhile, *A. niger* grows optimally at temperatures of 35-37ºC (range from 6 to 47ºC) and at low values of aw (0.77) (Duarte et al., 2010). *Aspergillus* species also are known as the most important fungal species able to produce aflatoxins, particularly *Aspergillus flavus* and *Aspergillus parasiticus*. At temperatures of 25, 30 and 35ºC biosynthesis pattern of aflatoxin followed the growth rate and was high at 0.99 aw and low at 0.90 aw. Highest amounts of aflatoxin were produced between 25 and 30ºC, but also under temperatures of 20ºC. However, very low amounts of aflatoxin were produced at more than 37 ºC and aw values of 0.90 (Schmidt-Heydt et al., 2008).

One of the most important diseases produced by *Fusarium* spp. that recently re-emerged is fusarium head blight (FHB) (Muthomi et al., 2008). *Fusarium* spp. is known to produce zearalenone and trichothecenes, such as deoxynivalenol and nivalenol. *Fusarium culmorum* and *F. graminearum* grows over a wider aw range (0.90-0.99) at 15 and 25ºC, while a water activity of 0.95-0.99 was required for deoxynivalenol and nivalenol production at the same range of temperature. The highest concentration of deoxynivalenol and nivalenol levels were produced at 25ºC and with aw values of 0.995 and 0.981, respectively, after 40 days of incubation (Hope and Magan, 2003). It is well documented that weather conditions influence different parts of the infection cycle, for example from prolonged period of warm humid conditions results in infections of cereal by *Fusarium* spp.

The biosynthesis of mycotoxins is highly regulated by external factors at the level of transcription. It has been reported that general growth parameters, such as substrate, water activity, temperature and pH, affect mycotoxins production (Reverberi et al., 2010). Schmidt-Heydt et al. (2008) described the influence of these abiotic factors by real-time PCR and microarray analysis on the expression of mycotoxin biosynthetic genes from *Aspergillus parasiticus*, *Penicillium verrucosum* and *Fusarium culmorum*, and concluded that aw, pH and temperature in a similarly way activated the genes for mycotoxin biosynthesis. Moreover, the results indicate that the expression of mycotoxin biosynthetic genes was observed close to optimum growth conditions and at moderate stress conditions (Schmidt-Heydt et al., 2008). More recently, the same team showed that certain combinations of aw and temperature, especially combinations which imposed stress on the fungus resulted in a significant reduction of the growth rate. At these conditions induction of the whole aflatoxin biosynthesis gene cluster occurred, however the level of produced aflatoxin B1 was low (Schmidt-Heydt et al., 2009).

Besides these abiotic factors it has been shown that certain conditions or the presence of several molecules can be a source of stress and consequently induce mycotoxin production. Jayashree and Subramanyam (2000) reported that higher levels of oxygen during trophophase trigger the aflatoxin production by *Aspergillus parasiticus*. According to the same authors, the results suggested that the biosynthesis of aflatoxin could be a consequence of an increasing of oxidative stress leading to enhanced lipid peroxidation and free radical generation. Furthermore, a study conducted by Narasaiah et al. (2006) support the idea that the formation of aflatoxin and its precursors, such as norsolorinic acid, versicolorin and O-methyl sterigmatocystin, by A. parasiticus may occur as a compensatory response to reactive oxygen species accumulation (Narasaiah et al., 2006). The effect of light on ochratoxin A production of *Aspergillus carbonarius*, *A. niger, A. steynii* and on *Penicillium nordicum* and *P. verrucosum* was dependent on the fungus and growth medium but generally the light had negative effect on ochratoxin A biosynthesis (Schmidt-Heydt et al., 2011). Schmidt-Heydt et al. (2007) described the positive effect of suboptimal concentrations of preservatives, such as potassium sorbate and calcium propionate in biosynthesis of ochratoxin A by *Penicillium verrucosum*. The ochratoxin A production was stimulated by 150 and 300 mg/L of both preservatives, particularly at values of aw 0.95 and 0.93. Additionally, these authors showed that if water activity as a single factor was modified, a typical ochratoxin A production and otapksPV expression profile occurred, indicating that ochratoxin A synthesis is activated under optimal growth conditions and under weak stress conditions (Schmidt-Heydt et al., 2007).

As it was previously described and is generally accepted, stress is mentioned as a factor that switchs on mycotoxin biosynthesis (Schmidt-Heydt et al., 2008). Meanwhile, mycotoxin could be detected after fungus died as they are usually stable for a long period of time (Ayalew et al., 2006).

The changes in weather conditions and the modifications of the biogeographical scenarios of crop cultivation could trigger the adoption of new GAPs targeted to face fungal contaminations and mycotoxin synthesis (Miraglia et al., 2009). Furthermore, the direct relation of the infection to environmental factors makes possible to focus the future research in the following points (Miraglia et al., 2009): harmonization of procedures for the surveillance and monitoring of mycotoxins across Europe; evaluating the feasibility of a database on the geographical distribution of mycotoxins; development of models for the prediction of the novel biogeographical agricultural scenarios of cultivated plants and of the related moulds/mycotoxins; assessment of the influence of multiple environmental factors on mycotoxin contamination.

It seems of consensus that the production of mycotoxins can be regarded as an adaptation to imposed abiotic and other stress factors by several fungus strains. The pathway of mycotoxin biosynthesis is activated under optimal growth conditions and under weak stress conditions. However, if two or more factors are at suboptimal values the toxin gene expression ceases. Whether the activation of mycotoxin is the cause or the consequence of a stress reaction is still yet unknown. Taking into account all the considerations of this section the best control strategies in order to avoid wheat contamination by mycotoxins is to ensure the complete inhibition of fungal growth strains.

Table 2. Occurrence of mycotoxins and contamination ranges.

Mycotoxin	Country (year)	Positive samples (%)	Contamination range (µg/kg)	Reference
Aflatoxin B1	Ethiopia (1999)	4.2	n.d. - 12.3	(Ayalew et al., 2006)
			n.d.- 1388.0	(Qutet et al., 1983)
	Kenya (2004)	41.0	0 - 7.0	(Muthomi et al., 2008)
Ochratoxin A	Poland (1998)	48.6	0.60 - 1024	(Czerwiecki et al., 2002)
	Ethiopia (1999)	23.4	4.2 - 66.0	(Ayalew et al., 2006)
	Bulgarian		0.5 - 39.0	(D´Mello, 2004)
	Italy (1999-2000)	8.6	n.d. - 1.4	(Palermo et al., 2002)
	Morocco	40	0.04 - 0.80	(Zinedine et al., 2006)
	Tunisia	38	n.d. - 940	(Zaied et al., 2009)
Deoxynivalenol	Ethiopia (1999)	16.7	50 - 110	(Ayalew et al., 2006)
	Kenya (2004)	75.0	105 - 303	(Muthomi et al., 2008)
	Germany (2006)	n.d.	20 - 2960	(Muller et al., 2010)
	Germany (2007)	n.d.	n.d. - 20320	(Muller et al., 2010)
Nivalenol	Ethiopia (1999)	4.3	40 (1 sample)	(Ayalew et al., 2006)
	Japan		4400	(Yoshizawa, 1997)
Zearalenone	Ethiopia (1999)	0	0	(Ayalew et al., 2006)
	Kenya (2004)	60	1.6 - 35	(Muthomi et al., 2008)
	Germany (2006)	n.d.	< 2.0 - 6.0	(Muller et al., 2010)
	Germany (2007)	15.6	n.d.- 2543	(Muller et al., 2010)

3. Industrial durum wheat processing

3.1. Production of pasta

A quality pasta product requires high quality raw material (Toussaint-Samat, 1992). Durum wheat, which preserves for a long time its qualities and nutritional value (López Bellido, 2009), being ideally suited for pasta, is weighed, sampled and analyzed, passed through a preliminary cleaner and magnet, then stored according to grade. Meticulous cleaning is also required for durum wheat. Cleaners remove weed seeds, dirt and other extraneous material through machines which separate by size, specific gravity, and shape. Frictional cleaning equipment (scourers) scours the surface of the kernel, removing the outermost layers of the bran. Therefore the grains are tempered. During tempering, water is added to toughen the outer bran coats for easier separation from the endosperm. Tempering also mellows the endosperm for grinding. Durum wheat is usually tempered for a relatively short time, yet some technology in pasta manufacturing also enables finer semolina to be used for longer tempering periods.

In the industrial production of pasta (Lidon and Silvestre, 2007) milling is essentially a grinding and separating development. Grinding is done on break rolls, sizing rolls and reduction rolls. Separation is carried out using sifters and purifiers machines. A durum mill has an extended break system in which grinding is relatively gradual. The endosperm is released in coarse granular form rather than as flour. The grading, purifying and sizing systems are more extensive in a durum mill, but the reduction system is very small compared to that of a flour mill.

The main product of durum milling, the so called semolina, is coarser than the flour produced in common wheat milling (Toussaint-Samat, 1992). Desirable characteristics for semolina include good colour, minimum dark or bran specks and uniform granulation. Small amounts of fine semolina and flour are produced. These are often combined with normal semolina to obtain blended material that can be used for a wide range of long and short pasta types. The semolina is stored in silos that can hold up to 68,100 kg. To manufacture the pasta, pipes move the flour to a mixing machine equipped with rotating blades. Warm water is also piped into the mixing machine.

The mixing can be prepared using an automatic continuous mixer or with semi-automatic batch mixers. In the former case the ingredients are blended and dosed automatically in a centrifuge according to pre-programmed recipes. In semi-automatic batch mixing ingredients are dosed manually, with the mixing being prepared in a secondary hopper and transferred to the forming machine only when the batch is ready. The mixture is kneaded to a paste consistency.

To develop flavored and colored pasta, eggs can be added to the mixture if the product is an egg noodle. If pasta is to be a flavored variety, vegetable juices can be added. A tomato or beet mixture is added for red pasta, spinach for green pasta, carrots for orange pasta. Herbs and spices can also be folded in for additional flavoring. Food additives can be added, to fresh pasta, in order to obtain quality products with the requirements of the consumers.

For product forming, the dough can further be shaped into non-filled pasta through extrusion, shaping on a belt and lamination (Lidon and Silvestre, 2007). Extrusion allows producing the wider range of products in the easier way. The dough is compressed at high pressure and forced through the tiny holes of a die. A die is a basic component of a press: the dough, formed in the kneading tank and then driven by the extrusion screw towards the head of the press, is forced through the die. A die is composed of a main support, normally made of bronze. This support is drilled with special techniques and each hole is made to house a drawing insert. The shape and type of insert determines the final shape of the pasta. The dough is pressed through the insert, which provides the basic structure of the pasta (tube, hollow, spiral). Behind the die there is often an additional structure that bends, folds or cuts the pasta to form the final shape. The classic material for the insert is bronze, which is still entirely used to make traditional dies. Dies made entirely of bronze have the feature of giving the surface of the pasta a minutely jagged and porous appearance, with highlights making it look white: this is a direct consequence of the nature of the material used for the die since the surface of bronze is never perfectly smooth. The extruded pasta is then cut to the desired length. This process is used to produce the better known shapes of non-filled pasta, like spaghetti, maccheroni, fusilli, penne, and more complicate shapes like radiators or wheels.

Shaping on a belt allows only the production of special shapes, traditionally twisted or dragged by hand (Giese, 1992). The dough is twisted and dragged on a conveyor belt to simulate the work of the hand and obtain the desired shape, like trofie, cavatelli, olive leaves, etc. Even though all pasta is produced with the same raw materials, each shape, in a certain sense, has its own personality: as regards, for instance, the type of sauce that best goes with it; or the way of using it, with meat or vegetable stock, or drained and served with sauces of every kind. Pasta shapes stimulate culinary creativity because they are themselves the outcome of a creative process. The countless shapes of pasta are the basis for thousands of possible recipes, each one different and characteristic.

In the lamination process the mixture is pressed into sheets by large cylinders. A vacuum mixer-machine further flattens the dough while pressing air bubbles and excess water from the dough to reach the optimum water content of 12%. Laminated pasta or pasta shaped on belts sometimes is sold fresh. In this case the product is pasteurized (overheated for a short time to reduce bacteria charge) to increase its shelf-life. Pasta is carried by conveyor belts through a pasteurizing tunnel and then through a cooling tunnel. All the process can be automatic and continuous without contacts with the operator.

Depending on the pasta shape to be produced, the dough is either cut or pushed through dies (Lidon and Silvestre, 2007). Ribbon and string-style pasta such as fettuccine, linguine, spaghetti, and capellini (angel hair pasta) are cut by rotating blades. Making pasta in a tube or shell shape such as rigatoni, ziti, elbow pasta, macaroni, and fusilli, the dough is fed into an extruder which then pushes it through metal dies. The size and shape of the holes in the die determine the type of pasta. Making pasta shaped like vermicelli and capellini, the pasta dough is pushed through holes between 0.8-0.5 mm in diameter. The cutting machine then cuts the pasta into lengths of 25 cm and twists it into curls or left straight. Tortellini (filled pasta) is made on a separate machine. The machine cuts small circles from a roll of dough. A bucket of ricotta cheese or filling mixture drops a pre-measured amount of filling onto the circle of dough. The dough is then folded over and the two ends are joined to form a circle. This is referred to as a tuck and fold machine. To make ravioli (filled pasta squares), pre-measured quantities of cheese or filling are dropped by a machine at pre-measured intervals on a sheet of pasta. Another sheet of pasta is placed over this sheet as it moves along a conveyor belt. The two layers then pass under a cutting machine that perforates the pasta into pre-measured squares.

Drying is the thermal process more widely used to preserve non filled pasta (Lidon and Silvestre, 2007). Humidity rate of the product is significantly reduced in suitable drying rooms according to proper temperature and humidity cycles. Drying cycles are critical to obtain a good result. Drying cycle can be completely automatic on conveyor belts for high productions or semi-automatic on trays and trolleys for lower productions. The pasta is placed in a drying tank in which temperature, moisture and drying time are strictly controlled.

The drying period differs for the various types of pasta. The drying time in making pasta can range from three hours for elbow macaroni and egg noodles to as much as 12 hours for spaghetti. The drying time is critical because if the pasta is dried too quickly it will break and if it is dried too slowly, the chance for spoilage increases. The oxygen level in the tank is also controlled, and lab technicians test frequently for salmonella and other bacteria. Careful handling of the pasta during the drying period is also crucial. Spaghetti is the most fragile of the noodles and is therefore hung high above the floor.

For packing, fresh pasta is folded in pre-measured amounts into clear plastic containers (Lidon and Silvestre, 2007). As the containers move along a conveyor belt, a plastic sheet covers each container and is sealed with a hot press. At the same time, a small tube sucks the air from the container and replaces it with a mixture of carbon dioxide and nitrogen to prolong the product's shelf-life. Labels listing the type of noodle, nutritional facts, cooking instructions and expiration date are attached to the top of the containers. Dried pasta is loaded, either manually or mechanically, into stainless steel buckets which move along a conveyor belt to the appropriate packaging station. The pasta is measured by machine into pre-printed boxes, which also list the type of noodle, ingredients, preparation and expiration date.

To assess the quality of pasta, the semolina flour for color, texture and purity are tested before it is removed from rail cars (Lidon and Silvestre, 2007). Protein and moisture content are also measured. The technicians constantly further test the pasta for elasticity, texture, taste and tolerance to overcooking. Plant workers are required to wear helmets and plastic gloves. Mixing machines must also be scrupulously cleaned after each batch of pasta passes through them. The drying process is strictly monitored to guard against spoilage.

3.2. Food additives requirements

Fresh pasta foodstuffs are appreciated by consumers for its organoleptic characteristics, nutritive value, preservation, simplicity and security in use. In order to obtain quality fresh pasta products with the requirements of the consumers, namely a good appearance, tasty, that could be preserved for a longer period of time as possible, food additives are often used. However, only a few additives are allowed to be used in fresh pasta and no additives can be added to dry pasta. Fresh pasta requires food additives (Table 3) that can act as acidifiers (substances that increase the acidity of a food product and/or give it a sour taste), acidity regulators (substances that modify or control the acidity or alkalinity of a foodstuff), antioxidants (substances that prolong the shelf-life of food products, protecting them from deterioration caused by oxidation, like rancidity of fats and colour changes), emulsifiers (substances that make it possible to produce or maintain a homogeneous mixture of two or more immiscible phases, such as oil and water, in a food product), preservatives (substances that prolong the shelf-life of food products, protecting them from deterioration caused by microorganisms), sequestrants (substances which form chemical complexes with metallic ion), flavouring agents (additives that give food a particular taste or smell, and may be derived from natural ingredients or created artificially) and colours (substances which add or restore colour in foodstuffs).

All these food additives can be used in quantum satis, which mean that no maximum level is specified. However, additives must be used according with good manufacturing practice, at a level not higher than the necessary to achieve the intended purpose and provided that they do not misled the consumers (Directive, 1995). Although a large number of food additives used in food industry can have side effects for the consumer, the additives allowed in fresh pasta are considered non-hazardous. In this context, the food additive E270 - Lactic acid, known by the chemical names of 2-hydroxypropionic acid and 1-hydroxyethane-1-carboxilic acid, is colourless or yellowish, nearly odourless, syrupy liquid with an acid taste, being often used with the technological functions of acid, acidifier, and preservative and obtained by lactic fermentation of sugars (but can also be prepared synthetically) (Directive, 1996). Ascorbic acid (E300), white or almost white, odourless crystalline solid which darkens on exposure to light, freely soluble in water, sparingly soluble in ethanol and insoluble in ether, also with the chemical names of L-ascorbic acid 2,3-Didehydro-L-threo-hexono-1,4-lactone and 3-Keto-L-gulofuranolactone, is the most important natural antioxidant used as antioxidant in fresh pasta, protecting against deterioration caused by oxidation and extending the shelf-life of food. Sodium ascorbate (E301), white to slightly pale greyish-yellow odourless crystalline powder, freely soluble in water and very slight soluble in ethanol, with the chemical names of sodium ascorbate, sodium L-ascorbate, 2,3-Didehydro-L-threo-hexono-1,4-lactone sodium enolate and 3-keto-L-gulofurano-lactone sodium enolate, is also an important antioxidant used in fresh pasta. Lecithin (phosphatides or phospholipids) is a natural food additive (E322) that can act as emulsifier and antioxidant in fresh pasta, making possible the formation and maintenance of homogeneous mixtures between two or more immiscible phases (namely oil and water), and can also extend the shelf-life by preventing oxidation. Lecithins are mixtures or fractions of phosphatides obtained by physical procedures from animal or vegetable foodstuffs; they also include hydrolysed products obtained through the use of harmless and appropriate enzymes (the final product must not show any signs of residual enzyme activity). The appearance of this food additive ranges from the brown liquid or viscous semi-liquid or powder depending on the source and whether it is bleached or unbleached and the hydrolysed lecithins are light brown to brown viscous liquid or paste. Citric acid (2-hydroxy-1,2,3-propanetricarboxylic acid, β-hydroxytricarballytic acid), a white or colourless, odourless, crystalline solid, having a strongly acid taste very soluble in water, freely soluble in ethanol and slightly soluble in ether, is a food additive (E330) naturally present in citric fruits, which is used as acidulant, sequestrant, synergist for antioxidants, and flavouring agent of fresh pasta. This additive extends the shelf-life, acting against oxidation processes, and has no side effects to the consumer. L(+)-Tartaric acid (L-tartaric acid, L-2,3- dihydroxybutanedioic acid, d-α,β-dihydroxysuccinic acid), a colourless or translucent crystalline solid or white crystalline powder, is an acidifier (E334) used to reduce the pH of fresh pasta, acting as obstacle against the microbial development (Nanu-Pacuar and Danciu, I., 2008). This additive can act also as synergic for antioxidants, sequestrant, and flavouring agent (FAO, 2011). Mono- and diglycerides of fatty acids (glyceryl monostearate, glyceryl monopalmitate, glyceryl monooleate, etc., monostearin, monopalmitin, monoolein, etc. or GMS (for glyceryl monostearate)) is an emulsifier (E471) used in fresh pasta (FAO, 2011) that can be from natural origin or can be synthesized from glycerin and fatty acid oils and fats. This additive is a mixture of mono- and diglyceryl esters of long chain saturated and unsaturated fatty acids that occur in food fats which contains at least 30% of alpha-monoglycerids and may also contain other isomeric monoglycerides, and di- and triglycerids, free glycerol, and free fatty acids. The product, that is insoluble in water, and soluble in ethanol, chloroform and benzene, varies from a pale yellow to pale brown oily liquid to a white or slightly off-white hard waxy solid, and the solids may be in the form of flakes, powders or small beads. Glucono-delta-lactone (Gluconolactone, GDL, D-gluconic acid delta-lactone, delta-gluconolactone) is the cyclic 1,5-intramolecular ester of D-gluconic acid, and can be used as food additive (E575) with the functions of acidifier, razing agent and sequestrant in fresh pasta. This natural substance can be obtained by oxidation of glucose and doesn't have secondary effects known. This additive is a fine, white, nearly odourless, crystalline powder freely soluble in water, and sparingly soluble in ethanol (Directive, 2000). Fresh pasta products can also contain some natural colours and flavoring agents, or can be manufactured with ingredients that give cretin colors and flavors but are not considered food additives, such as eggs, spinach, tomatoes, etc.

Table 3. Food additives used in fresh pasta that are allowed by the European Union law.

E Nº	Chemical name	Chemical formula
E270	Lactic acid	$C_3H_6O_3$
E300	Ascorbic acid	$C_6H_8O_6$
E301	Sodium ascorbate	$C_6H_7O_6Na$
E322	Lecithins	A chemical mixture
E330	Citric acid	(a) $C_6H_8O_7$ (anhydrous) (b) $C_6H_8O_7.H_2O$ (monohydrate)
E334	L(+)-Tartaric acid	$C_4H_6O_6$
E471	Mono- and diglycerides of fatty acids	(mixture)
E575	Glucono-delta-lactone	$C_6H_{10}O_6$

Conclusion

Through the years, the breeding programmes over the world have been able to provide germplasm with high-yielding, management-responsive and input-efficient. The ultimate goal is to simultaneously increase yield and improve end-use grain quality of durum wheat in developing countries. Although environmental factors, such as maximum temperatures and water available during grain filling period, have important effects on wheat grain protein accumulation and quality for pasta technology, durum wheat quality is a genotype-dependent trait. In general, moderately high temperature, proper soil moisture (resulting from rainfall and irrigation) and adequate solar radiation may improve durum wheat quality. Some ecological factors, including soil physiological and chemical properties and geographic latitude, can also affect durum wheat quality. Nevertheless, wheat infections caused by phytopathogenic fungal strains can also have relevant implications, through mycotoxins production, at economical and on human health as well. Indeed, mycotoxins can be regarded as an adaptation to imposed abiotic and other stress factors by several fungus strains. Following a general perspective, the production of pasta requires high quality requires high quality raw material, yet although all food additives can be used in quantum satis, following good manufacturing practice, their levels must not be higher than the necessary to achieve the intended purpose.

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