

Chapter

Durum Wheat: Uses, Quality Characteristics, and Applied Tests

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Abstract

Durum wheat (*Triticum durum*) is a commercial and most important cultivated tetraploid species of wheat. Most of the durum wheat is used for pasta-making. It is also used for bread-making. In the last decades, the popularity of bread made from durum wheat is increasing. The majority of people from the milling and baking industry are not very familiar with this special wheat. The purpose of this work is to present the quality characteristics of durum wheat and the tests applied. A better understanding will have a positive influence on the final quality of the product. It will also increase the commercial appeal of the durum wheat and create alternative markets, especially in years of over production. The durum wheat has harder grain texture and stiffer gluten compared to common wheat (*Triticum aestivum*). Most of the tests applied are common for both wheat species and describe to a greater extent, the quality characteristics of the durum wheat. Although there is a developed and recognized international bread-making procedure, there is a need to develop the same specifically for durum bread.

Keywords: durum wheat, durum semolina and flour, durum pasta and bread made with durum wheat, quality tests, grain quality

1. Introduction

1.1 Origin and genetic relationship of durum with other wheats

Cereals have been cultivated since 8000 BC [1]. Today, wheat is grown annually on about 215 million hectares, making it more widely grown than any other cereal [2, 3]. It is regarded as the most important food grain since it provides 20% of the total food calories to the global population. Among the grains, wheat is unique because its proteins have the ability to form gluten [4, 5]. The gluten trap the gas produced from yeast fermentation and contribute directly to the cellular structure of the bread [6].

All wheats belong to the genus *Triticum* and are divided into three groups according to the number of chromosome sets in their genome. These groups are diploid, tetraploid, and hexaploid. The major classes are hexaploid and tetraploid. Common wheat (*Triticum aestivum*) is the general name of the hexaploid wheat, while durum wheat (*Triticum durum*) is the most commercial important species of the tetraploid wheat [7].

1.1.1 Production

Durum wheat (*T. durum*) is a minor cereal crop. It represents 5% of the total 700 million tons of all wheat species produced annually [8].

While common wheat is cultivated almost everywhere in the world, durum wheat is mainly cropped in three main areas: Mediterranean, North plains between USA and Canada, and in the desert areas of southwest of USA and northern Mexico. The reason is that a dry climate with hot days and cool nights especially, during harvesting period, favor durum wheat's critical quality characteristics like vitreosity and color [9].

The European Union (EU) is the largest producer and consumer of durum wheat. Italy, France, Spain, and Greece produce approximately 80% of the Union's annual production [8]. Durum wheat produced in France is generally regarded as the best in the EU. Italy is the largest pasta producer and consumer of durum wheat worldwide. Canada is the largest and the second largest exporter and producer, respectively. The durum wheat produced in Canada and USA is considered of premium quality, and. Countries such as Mexico, Australia, Turkey, Kazakhstan, Morocco, and Tunisia are also regarded as significant durum wheat producers [8].

1.1.2 Use of durum wheat

Most of the durum grain is used for pasta-making. It is also used to produce bulgur, couscous, and a range of traditional products. In addition, it is used for the production of traditional breads, especially in the Mediterranean countries (**Figure 1**). In some Middle Eastern countries, the majority of the durum wheat produced is directed to bread-making [10]. In Italy, more than 10% of the durum wheat consumed is destined for bread production. Lately, it has been observed that there is a trend of using durum wheat flour for bread-making outside the Mediterranean Basin, in countries like Russia, Canada, and USA [11, 12].

Durum in Latin means “hard” and the species is the hardest of all wheats. Durum milling a coarse particle called semolina is produced and is ideal for making pasta and couscous. During milling, hard wheat shatters into coarse fragments and offers high yield of semolina. The objective of a mill diagram of the so-called semolina mills is to produce the maximum semolina and the lowest possible flour. Uniform semolina particles hydrate evenly when the dough is developed, whereas flour tends to congregate together in pockets within the dough and to form uneven and undesirable streaks in the extruded pasta. Durum wheat semolina produces products with good cooking quality, stability to overcooking and good eating quality. The key features of durum wheat are its hardness, intense yellow color, and nutty taste. In



Figure 1.
Products made from durum wheat, from left to right, pasta, couscous, and bread.

many countries such as Italy, France, and Greece, it is obligatory by law that pasta should be produced solely from 100% durum wheat semolina. Other countries such as USA, Canada, Spain, and Australia by choice use durum wheat semolina for pasta production [13].

Common wheat is the raw material of choice for leavened or flat bread. However, specialty breads are also made from durum wheat flour, and these breads are not produced industrially. There is a general agreement that durum flours produce smaller loaf volumes than those of common wheat [14]. The reason is that the gluten properties of durum are inferior to those of common wheat [15–18]. The durum bread has yellowish color, uniform crumb structure, nutty taste, and the crust is usually darker and has more prolonged self-life compared to bread made from common wheat, making it an appealing choice to consumers [10–14]. There is a considerable interest in increasing the commercial appeal of durum wheat flour. Durum wheat flour with good consistent baking quality is a desirable goal for farmers because in years of high production, durum wheat would have alternative markets. Developing dual-purpose durum wheat which will be suitable for both pasta- and bread-making is the scope of several breeding programs in Italy and Canada [13].

2. Grain quality

Products made from durum wheat have relatively simple manufacturing processes and in most cases, is the most important ingredient. Therefore, the quality characteristics of the grain have a very critical impact on the finished product quality. Pasta makers, millers, and bakers apply sophisticated analytical tests and devices to predict end-product quality [19].

2.1 Grain size: 1000 Kernel weight

Premium durum wheat is 30% larger than common wheat. The acceptable 1000 kernel weight is above 38 g/1000 kernels, in other words, the weight of 1000 kernels of durum wheat should be above 38 g. Large kernels are positively related to the endosperm quantity; therefore, is of great economic consideration for the milling industry.

2.2 Test weight

Test weight (TW) is a widely used specification method in wheat grading. It is a recognized index of wheat soundness and milling potential [20]. Factors affecting test weight are wheat moisture content, kernel density, grain size, and shape. In most cases, TWs > 76 kg/hL are desirable. Durum wheat test weight is negatively correlated with protein content. Test weight is regarded as a better estimator of durum wheat milling performance compared to kernel weight [21].

2.3 Grain size distribution

It is of great technological importance that the grain for milling should have uniform size as much as possible. The reason is that during durum wheat conditioning, water hydrates faster with the smaller grains, and water penetration in the endosperm makes it softer. The soft endosperm breaks into small particles which are lost to the semolina mill stream, which is an economic loss [22].

2.4 Grain hardness

Grain hardness is of great importance because it is strongly correlated with semolina yield [23]. The Perten's instrument called Single Kernel Classification System, commonly referred as SKCS, is used to measure the kernel hardness [24].

2.5 Vitreous kernels

Hard vitreous kernels is an important grading factor. Protein is strongly and positively related with durum kernel vitreosity. Sufficient protein guarantees that starch granules are bound together. Otherwise, the free starch granules break into small particles, adding to the low value fines mill fraction [25–28]. Vitreous kernels are translucent, while nonvitreous wheat kernels are opaque. Therefore, white semolina spots may be visible in dried pasta, impacting negative attraction of the product [29]. Nonvitreous kernels contain a lower proportion of gliadins [30]. Environmental factors such as rainy weather during harvesting and insufficient fertilization along with genetic factors impact negatively the durum's wheat protein content and vitreosity [31, 32]. Hard vitreous kernels counts or HVK expressed in % and the most commonly used method is ICC Standard Method 129 (ICC 2001).

2.6 Grain moisture

The moisture content of durum wheat must not exceed 12.5% w/w, above this point, the grain cannot be stored safely in bulk. Excessive moisture can cause fungal spoilage and local areas of high heat may lead to explosion [33].

Grain moisture can be determined either by using near-infrared (NIR) analysis or by an air oven [34].

2.7 Ash content

Ash content can be defined as the inorganic residue remaining on complete combustion of all organic matter from measured mass of grain [35].

Ash content is a measure used to define the extraction rate of semolina. The higher the ash content, the higher the extraction rate and the higher the bran contamination. The most inorganic compounds are found in the bran layers. High bran layers can cause defect in pasta browning. Durum wheat batches with high ash content can lead to semolina with high ash content [19].

2.8 Black point

Black point is an important grading factor for durum wheat as well for common wheat and barley (*Hordeum vulgare*). It is a distinct dark or brown discoloration of the germ and the surrounding area [19]. The cause of this discoloration is not well understood but believed to be due to phenolic compounds located in the kernel pericarp activated by humid conditions during grain filling [36]. Top durum grades characterized by minimum black specks appear to the consumers as undesirable contaminants. However, black point has little effect on semolina milling yield, semolina ash content, and pasta cooking quality [37]. The Satake Corporation and the Buhler Group claim that their debranning technologies, Peritec, and DC Peeler, respectively, can reduce the black point contamination to the minimum [38, 39].

2.9 Mechanical dockage test and foreign material

Dockage can be defined, as any other material such as weed, chaff straw, oilseed that can be found in a parcel of wheat and can be removed by the use of appropriate sieves, cleaners, and aspirators. Contamination of durum with seed from cereals like bread wheat and barley and even worse with oilseed species will lead to significant quality issues [19]. Maximum permissible levels of foreign material are indicated in ISO Standard 11,051.

2.10 Frost damage

Durum wheat grown in Western Canada and in Northern United States is vulnerable to frost damage. Air temperature below -3°C during grain filling can result in frost damage. Grains surviving from freezing can be distorted and shriveled [19, 40]. It is difficult to quantify the degree of frost damage. The main effects of moderate frost damaged durum wheat were the decline in test weight, the loss of semolina yield, and the higher semolina ash content. Also, pasta was less bright but cooking quality remained unaffected [41].

2.11 Sprout damage

Humid weather conditions during the harvesting period may cause durum sprouting. The elevated activity of α -amylase can have detrimental effects on bread-making. Excessive durum wheat sprouting leads to high dough stickiness, poor crumb structure, low bread volume, and excessive crust browning [42]. Although, sprout damage is negatively related with kernel vitreosity and semolina yield, it appears to be less of a quality problem in pasta manufacturing. Numerous studies and reports concluded that sprout damage has little influence on pasta quality unless the activity of α -amylase is very high [28, 43, 44]. Heavy sprouting on durum wheat can cause redness in pasta dried at a high temperatures [45]. Also, studies have found that extremely low falling number, that is below 100 will lead to cooking loss and the pasta becomes less firm [46].

The most common method used to determine the level of α -amylase activity of the durum wheat is the falling number (**Figure 2**) [47, 48].

2.12 Ergot: (*Claviceps purpurea*)

Ergot is a fungal disease that attacks cereals. Gravity tables in milling houses are required for cleaning and removal of grains infected with ergot because ergot bodies pose a serious health threat. Severe mycotoxicoses can be caused in case of extreme consumption of wheat infected with ergot. Symptoms include disorders of the nervous system and contraction of blood vessels, leading to gangrene and gastrointestinal disorders [49]. In order to ensure safety, the Canadian Grain Commission has imposed strict limits for ergot; even for the lowest grade of durum wheat. According to the Canada Western Amber Durum (CWAD), only 0.04% and less is acceptable [19].

2.13 Fusarium head blight (*Fusarium. graminearum*)

Fusarium head blight (FHB) caused by several species of *Fusarium* fungi, sometimes referred as pink-stained grain, is a fungal disease of small-grain cereals that is



Figure 2.
Pertten Falling Number device, PerkinElmer Sverige AB, Hågersten, Sweden.

a food safety concern because of the presence of toxic mycotoxins in infected grains. These toxins are extremely harmful both to human and animals. Pasta and bread made from contaminated semolina or flour will contain mycotoxins [50]. They can cause vomiting, feed refusal, bloody diarrhea, dermatitis among others symptoms [51].

Continuously warm and humid conditions for days during anthesis favor the development of *Fusarium* head blight [19]. Grain buyers monitor the presence of FHB by reference to photographic standards (e.g., see Visual Recognition Standards Guide at www.Graintrad.org.au).

2.14 Heat damage

During wet harvests, growers can harvest durum wheat above 12.5% moisture and dry the grain by hot air in specifically designed silos for this scope. However, drying wheat above a critical temperature can cause serious quality damage. Drying temperature above 50°C will damage gluten protein functionality, which will be evident on durum flour bread-making performance. Although, in case of pasta-making, studies [30] have shown that drying durum wheat to 17% moisture at 50°C caused no

detectable effect on pasta cooking loss, even at 70°C, the effect on pasta quality was moderate. The spaghetti cooking quality became unsatisfactory when durum was dried at 85°C.

Extensive work has been done to develop rapid methods to detect heat damage [52, 53]. A study has shown that near-infrared (NIR) spectroscopy technology could be used to detect heat damage [54].

2.15 Protein content

Protein content is a key quality factor influencing pasta-cooking quality and bread-making performance [55–58]. Durum wheat protein can account for 30–40% of the variability in pasta-cooking quality. It is generally accepted that durum wheat exceeding 11.5% protein content can be used for pasta making, while below 11.5% regarded of poor quality and it used as feed for livestock animals. Protein content is positively related with grain hardness and semolina extraction [59].

Pasta made from high protein semolina is stronger, more elastic compared to lower-protein content semolina. Generally, high protein semolina is less sticky and highly resistant to overcooking pasta. On the other hand, couscous quality is less affected by protein quantity. It should be noted that high protein durum wheat is associated with lower test weight, duller semolina, and lower semolina yield at a given ash content [60]. The duller semolina color results in duller pasta and as the protein increases, the pasta becomes browner. However, millers and pasta makers should always remember that the benefit of better pasta texture as protein increases more than compensates for the negative quality aspects [61]. NIR is the most common method used to measure the protein quantity of durum wheat [62].

2.16 Protein quality

The combination of water into flour and the mechanical energy input leads to the formation of a continuous cohesive visco-elastic network [63]. The time needed for full dough development and the dough resistance during mixing, is highly related with the gluten properties. So the mixing strength of semolina and durum flour is largely determined by the strength of the developing gluten matrix [63]. Strong dough retains its shape during extrusion and the pasta retains its shape and integrity during cooking and the cooked product provides the desired textural properties when eaten. The gluten matrix holds the starch granules and prevents the dissolution of the starch particles into the boiling water which otherwise will cause pasta stickiness. In bread-making the gluten matrix holds the air bubbles developed during kneading [63]. The gas retention capacity during fermentation and baking is therefore determined in a great extent by the gluten elasticity and extensibility. It allows the dough to expand by trapping the CO₂ produced by yeast while it prevents early bubbles rupturing through enhanced surface elasticity [64].

The most common classification of gluten proteins is based on structural characteristics and includes (1) the HMW prolamins, which include only the HMW-GS, (2) the sulfur-poor prolamins, which include ω -type gliadins; and (3) the S – rich prolamins, which include α - and γ -type gliadins and LMW-GS [65].

It is generally accepted that gluten quality and performance is greatly affected by two factors. The first factor is the gliadin to glutenin ratio of the gluten proteins. Glutenins due to their large size form a continuous network which determines the dough strength and elasticity [66], while the monomeric gliadins determine the

dough extensibility. It has been found that high glutenin to gliadin ratio was highly correlated with dough strength [67, 68]. These findings were confirmed by later studies which proved that by increasing the glutenin to gliadin ratio the dough strength is increased [69]. However, for optimum pasta-making and bread-making performance an appropriate balance between viscosity/extensibility, and elasticity is required [70]. The gluten strength is positively related with loaf volume. Although, if the gluten is too strong, the dough expansion during fermentation will be limited [71]. In contrast, in pasta-making, this attribute will allow pasta to maintain its shape [72].

The second factor is the quality of the glutenin polymer. Quality aspects such as glutenin composition, structure, and size distribution have a critical impact on bread-making performance. For example, the gluten elasticity may be affected by the difference in glutenin composition and the resulting noncovalent bond interactions [69]. In addition, it has been supported that the gluten elasticity is related with the size of glutenin polymer network [73]. It has been identified that the size of the glutenin network and the dough strength and bread-making performance are positively related [63, 74]. However, the extensive work on durum wheat protein of Edwards et al. [75] showed that the higher the proportion of HMW-GS, the lower the dough strength, in contrast to what is observed in common wheat. It has been found that the ratio of HMW-GS to LMW-GS is significantly negatively correlated with Alveograph parameters P, L, W, Gluten Index (GI), Mixograph parameters mixing time, and bandwidth at peak and % Unextractable Polymeric Proteins (UPP). In contrast, it has been observed [76] that an increase in total HMW-GS, increase the dough strength made from durum wheat. This led Edwards et al. [75] to suggest that the formation of a well-developed network of durum wheat would preferentially involve LMW-GS over HMW-GS. The later may not form a tangled network and may not be the primary strength contributor as in the case of common wheat. Edward et al. [75] further suggested that the strength is possibly based on an associative polymer type of structure involving LMW-GS, in which shorter chain lengths result in greater density of crosslinks and therefore leads to greater strength.

Genetically durum wheat is tetraploid and lack D genome found in hexaploid wheat [75]. It has been demonstrated [77] that the removal of D genome from common wheat had a negative impact in the bread-making performance of common wheat. Studies showed that the reduced extensibility and elasticity were greatly improved by the incorporation of D genome [78].

The largest part of durum wheat harvest is used in the production of pasta [79]. Therefore, durum wheat breeding programs focus on quality factors that are critical for pasta-making [13]. Durum wheat cultivars which exhibit very strong gluten characteristics are not well suited for high volume breads because they exhibit tenacious and inelastic gluten [10]. As it was noted earlier, an optimum bread-making performance requires an appropriate balance between dough strength and extensibility. The work of Redaelli et al. [78] showed that a promising strategy to improve the baking performance of durum wheat is to incorporate the D genome of common wheat to durum wheat. Breeding wheat suitable for both bread and pasta would increase the potential use of durum wheat. This has motivated many institutions in Italy and Canada to develop breeding programs for dual-purpose durum wheat. Another promising strategy is to cross strong durum wheat lines with weaker emmer (*Triticum dicoccum*). It has been reported [80] that these crossed samples showed dough extensibility and loaf volume increase, while the pasta-cooking quality was improved [9].

2.17 Protein quality assessment methods

A number of reliable methods for assessing and predicting the gluten and dough strength of durum wheat have been developed over the years. Sodium Dodecyl Sulfate Sedimentation (SDSS) is a simple test used widely across the durum wheat industry [21]. It measures the volume of sediment from suspension of ground wheat or semolina after a specified time, the higher the volume the stronger the gluten [81, 82]. Gluten Index (GI) is another popular method used to determine the gluten strength. It measures the proportion expressed in % of wet gluten that resists passing through a screen during centrifugation. The higher the proportion, the stronger the gluten [83, 84].

Empirical instrumental rheological tests which are used to assess common wheat quality are also applied for predicting the strength of the durum wheat dough. Usually, they are divided in two categories, the first include the dough kneading methods and the second the extensional methods.

The most common kneading methods are Farinograph, Mixograph, and Mixolab [85–89]. They measure the torque–mechanical resistance of the dough during mixing and kneading. The basic readings are the time needed for full dough development, the maximum resistance, and the dough resistance profile over a specified period of time. Strong dough is related with longer development time and higher and stable resistance profile over a period of time [90, 91].

The most common extensional methods are Extensograph and Alveograph [92–95]. The basic readings are the dough tenacity, extensibility, elasticity, and the overall work needed to rupture the dough. The main difference between the two methods is that the Farinograph extends the dough coaxial (in two dimensions), while the Alveograph blows the dough bubble biaxial (three dimensions) [96, 97].

3. Durum wheat milling

The aim of the miller is to extract flour as much as possible from the kernel with the minimum bran and ash contamination [98]. Wheat milling is regarded as gradual process, which can be divided into two major sections, the break and the reduction. The primary object of the break section is to separate the endosperm from the bran into fairly large pieces. While the primary object of the reduction section is to grind flour and semolina several times in order to meet the specified particle size of the finished product. Durum wheat is usually milled into the so-called semolina mills. The primary object of semolina milling is the high extraction of pure semolina and the minimal production of flour. Semolina milling systems traditionally have longer roll surfaces than the conventional systems used to grind common wheat. This is because by gradually reducing the durum kernel, the production of flour is minimized. The purification system has a pivotal role in the durum mill because the purifiers are the primary separators of the finished product and not the plan sifters as in conventional mills [72].

The traditional pasta-making process requires coarse particle semolina free from speck and barn contamination. The three most common granulations are

1. Semolina 1 “special” in the range of 630–200 μ
2. Semolina 2 and Middling in the range of 400–125 μ
3. Semolina 2 and Middling 2 in the range of 315–125 μ

Depending on the wheat quality, the semolina yield is approximately 68% and the flour ($\leq 125 \mu$) below 2%. Production of such coarse semolina with minimum speck count and ash content demands a very gentle grinding and great attention to any fluctuations [99].

New pasta production technologies allow the use of finer semolina granulation. The finer semolina is associated with the advantage of faster and more uniform water absorption and distribution. The advantage on the semolina production side is the lower production cost due to lower consumption of energy and the higher semolina extraction rate. The extraction rate of a fine semolina mill is approximately 75%, while for traditional coarse semolina is about 68%.

Durum flour used for baking applications requires finer particle size than this directed for pasta-making. During milling, great attention must be paid to starch damage content of the resulted flour. Because excessive or harsh grinding of such hard wheat as durum may lead to excessive starch damage. Usually, the particle size of durum flour is below 180μ . Semolina is remilled gently and gradually two to three times to be reduced into flour [99].

4. Semolina quality

Pasta makers pay equal attention to semolina visual appearance and to its rheological profile. The tests used for the latter such as Alveograph, Extensograph have been referred earlier.

4.1 Semolina color

Consumers regard pasta of good quality when it has a bright clean color. Reflectance spectroscopy can be used to assess the color of semolina, the space parameters are brightness (L^*), redness (a^*), and yellowness (b^*). A bright yellow semolina has (b^*) above 30.

4.2 Speck counts

Consumers also regard pasta of good quality when it is free of specks. They are regarded as potential contaminants. Ash content is an indicating factor of the specks present in semolina [100].

5. Pasta tests

5.1 Laboratory pasta-making tests

International recognized procedures for macro–micro scale lab pasta production have been established by AACCI International [101, 102]. The macroscale is an imitation of the commercial production process using an extruder that makes from 1.5 to 10 kg of spaghetti. The objective of the microscale process is to prepare spaghetti when small quantity of samples from early generation breeding lines are available.

5.2 Pasta color

Pasta color results from a desirable yellow component, an undesirable brown component, and a red component which is related with the drying conditions [103]. The yellow pasta color is dictated by the carotenoid content in the grain and the oxidative degradation of pigments by lipoxygenase during pasta processing [104]. The brown color masks the yellow color when it reaches at levels of 100 (L*) [103]. The red component of pasta is positively correlated with starch damage and α -amylase activity [105]. As they favor the formation of reducing sugars, this leads to the development of Maillard reaction products during pasta drying. This is more evident at high temperatures.

Instrumental color analysis of uncooked pasta is performed by reflectance spectrophotometric instruments [106].

5.3 Cooking quality tests

The ultimate test of acceptability of a pasta product is its cooking quality. Texture pasta quality characteristics are firmness, choosiness, elasticity, stickiness, and chewiness. Taste and aroma are also important quality characteristics. Cooking pasta attributes can be determined by sensorial, chemical, and instrumental tests [13].

5.3.1 Sensory tests

Sensory analysis tests are the ultimate tool for the measurement of the cooking quality of pasta products [107]. For this reason, an internationally recognized standard sensory method for pasta was developed [108]. However, such tests are expensive and time-consuming, and for these reasons instrumental tests are preferred for quality routine testing.

5.3.2 Cooking loss

Cooking loss can be defined as the percentage of starch leached into the water during pasta cooking. Quality pasta exhibits 7–8% residue of the pasta dry weight. An international standard method is available for measuring cooking loss [109].

5.4 Instrumental methods

Various instruments and tools have been developed to evaluate the pasta texture [110]. The most popular methods are those using texture analyzers as they are commonly called the Instron, the Lloyd, and the TA. XT2i Texture Analyzer. The main idea is to simulate the bite action and process and to measure the forces recorded and to translate them to a meaningful data related to pasta texture.

An international recognized procedure for evaluating the firmness of cooked pasta has been established [109]. Five strands of spaghetti are placed on the instrument and measured. Cooked firmness is regarded the total work recorded during the cutting cycle [19].

Another method which can be applied and can offer valuable data regarding the spaghetti stickiness and elasticity is the compression-retraction technique. Extensive work of [58] showed that the stickiness measurement by means of the TA-T2 texture instrument is closely correlated with sensorial tests.

6. Durum flour quality

Durum wheat is commonly used in traditional specialty breads in Mediterranean countries [9]. Many studies have shown that the physicochemical and rheological properties of durum wheat have a significant impact on the bread-making performance [15, 41, 70, 102]. In addition, the quality of durum wheat is heavily affected by agronomic practices, environmental conditions, and location [26, 32]. The rheological properties of the durum wheat and the major variation in quality may explain why these breads are not produced in industrial level [13].

The tests that commonly are used to describe the gluten strength, dough strength, and pasting properties of durum semolina and bread wheat are also applied for the assessment of durum flour.

The durum flour exhibits high Farinographic absorption capacity, fast dough development, and relatively low stability during kneading. Also, its dough is tenacious and inextensible. Typical Alveographic values are $P > 100$, $L < 60$, $W < 250$ [9]. It is also associated with lower sedimentation values compared to common wheat and relative high starch damage. The flour particle size in most cases is lower than $220\ \mu$. The Falling Number of durum is usually above 400 s, which are typical values for wheat grown in dry and hot climates [9]. According to Quaglia [10] in order to make good quality durum bread, the flour should have less than 7–7.5% starch damage, particle size lower than $190\ \mu$, protein content above 13%, P/L ratio > 1.5 , and $W < 200$. However, newer studies demonstrated that bread volume from re-milled semolina is not influenced by the size of the particles in the milling product [9]. Short fermentation times and remix-to-peak process favor the production of voluminous durum bread [111, 112]. The relative poor proving tolerance of durum flour is related with the absence of sufficient amount of HMW-GS.

Bakers regard good quality durum flour when it has a bright clean color and free of specks and bran particles. Reflectance spectroscopy used to assess the color of semolina can also be applied to durum flour. Typical ash content of durum flour ranges from 0.60 to 1.00. Millers usually employ NIR to measure the ash content in durum flour.

7. Bread-making quality tests

The ultimate test of acceptability of durum flour is its bread-making performance and end product quality. Bread volume, shape, and crust color are critical quality characteristics. Crumb texture and structure along with taste and aroma are also very important quality characteristics. Bread quality attributes can be determined by baking, sensorial, and instrumental tests.

7.1 Laboratory baking tests

The milling, institutional, or bakery laboratories follow their internal specified standard procedures, or they adopt the international recognized procedures for evaluating the bread-making performance of common wheat flour [113, 114].

7.2 Sensory tests

As stated above, sensory analysis tests are the ultimate tool for measurement of the quality of bread products. However, such tests are expensive and

time-consuming and for these reasons, instrumental tests are preferred for quality routine testing.

7.3 Instrumental methods

Various instruments and tools have been developed to evaluate the bread volume, crust color, crumb texture, and structure and all of them can be applied both to bread made from common and from durum wheat.

7.3.1 Bread volume

Volume is an important measure of fermented bread quality that has traditionally been determined by seed displacement method [115]. The last two decades many laboratories have replaced the said traditional method by Laser Topography—VolScan Profiler Method [116], since it is more accurate.

7.3.2 Crumb structure

Crumb structure characteristics of bread and other baked products are traditionally measured subjectively. The relatively new developed method called the C-Cell imaging system uses image analysis software to measure crumb structure characteristics of baked products [117].

7.3.3 Crumb and crust color

Consumers regard durum bread of good quality when the crumb color is bright yellow and the crust color is golden brown. Therefore, it is of great importance for millers and bakers to measure the color of both crust and crumb [14].

The color of the crumb can be determined by using Konica color reader [118]. It is used to determine the level of lightness of material, (L), redness, (a), and yellowness, (b), of the bread samples. If (b*) value is above 30, then crumb color is regarded as of good quality.

The color of the crust can be determined by pointing the color reader directly to the top surface of the crust. The L, a, and b values are indicated after the scanning process. L values around 50–52 are regarded as the optimum for durum bread crust.

7.3.4 Crumb texture, firmness, and elasticity

Bread firmness is a critical quality criterion for baked products, and of course, for durum bread and can be determined by the use of a universal testing machine. The objective of the measurement is to quantitatively determine the force required to compress a baked product by a preset distance. The firmness may be taken as a measure of freshness and quality [119].

8. Conclusion

Despite the fact that durum wheat represents approximately only 5% of global wheat production, it is the second most commercially important species of wheat after common wheat. Worldwide popular foods like pasta are made from durum

wheat semolina. Traditional breads made from durum wheat flour are becoming more and more attractive for consumers who are looking for ethnic style breads.

Products made from durum wheat have relatively simple manufacturing processes, in most cases, it is the most important ingredient. Consider the case of pasta or cous-cous, where durum wheat semolina and water are the only ingredients. Therefore, the durum wheat quality characteristics have a critical impact on the end-product quality. It has been referred that durum wheat lacks D-genome making its gluten stiff and inelastic and that it is the hardest of all wheat species. While these characteristics might be beneficiary for pasta quality, they impose challenges to durum wheat milling and to bread-making processes.

A number of reliable methods and tests have been developed to assess the quality of durum wheat and to relate it with the end-product quality. Although, according to author's knowledge, there is no international recognized bread-making procedure developed specifically for durum bread. The development of such method will help the scientific and baking community to further understand how the properties of durum flour affect the bread-making performance.

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