EFFECT OF DIFFERENT WHEAT VARIETIES ON PASTA QUALITY

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ABSTRACT

EFFECT OF DIFFERENT WHEAT VARIETIES ON PASTA QUALITY

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There are about 40 durum wheat varieties registered in Turkey. Around 10 varieties are being commonly cultivated. Amanos 97, Çeşit 1252, Ege 88, Fırat 93, Fuatbey 2000, Burgos, Kızıltan 91, Sarıçanak 98, Svevo and Zenith durum wheat varieties were used in this study.

Semolina and pasta have been produced in an industrial plant under constant process conditions from these varieties. In general, pasta quality is determined by three main factors, the raw materials, the production recipe and the production process. In this study, the production recipe and the production process were fixed and only durum wheat varieties were variable. So, the effects coming from the production recipe and the production process on pasta quality were eliminated.

Physical, chemical and sensory properties of these pasta were determined and the effect of different durum wheat varieties on pasta quality has been investigated to give a clear idea to the Turkish pasta industry about the most commonly grown durum wheat varieties in Turkey, hoping that Turkish pasta in domestic and international Markets will continue to grow with the help of clear understanding about the quality characteristics of the durum wheat they are using.

The important criteria of acceptability of pasta products is its cooking quality and cooking quality of pasta products is of importance to consumers and also to wheat producers, breeders and manufacturers. The pasta samples produced from Svevo, Zenith and Fırat 93 varieties got the higher scores than others in pasta cooking quality while those produced from Sarıçanak 98, Çeşit 1252, Kızıltan 91, and Fuatbey 2000 durum wheat were evaluated as relatively low. The main reasons of cooking quality differences can be interpreted as a result of the difference in protein quantity and quality of the varieties.

The bright yellow color of pasta products, rather than cooking behavior taste, is reported to be one of the most important considerations in assessing durum wheat quality. In this study, the pasta samples produced from Svevo, Zenith and Burgos varieties got the higher scores than others in pasta color (yellowness) while that produced from Fırat 93 had the lowest yellow color. The main reasons of yellow color differences can be interpreted as a result of the differences in carotenoid pigments, lipoxygenase and peroxidase enzymes contents of the varieties.

Keywords: Quality, Durum Wheat, Semolina, Pasta, Variety

ÖZ

DEĞİŞİK BUĞDAY ÇEŞİTLERİNİN MAKARNA KALİTESİNE ETKİSİ

Bozkurt, Murat
Yüksek Lisans, Gıda Mühendisliği Bölümü
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Türkiye'de 40'ın üzerinde tescil edilmiş makarnalık buğday çeşidi vardır. Bunların içinden yaklaşık 10 tanesi yaygın olarak yetiştirilmektedir. Bu çalışmada, Türkiye'de son yıllarda yaygın olarak yetiştirilen bu çeşitler (Amanos 97, Çeşit 1252, Ege 88, Fırat 93, Fuatbey 2000, Burgos, Kızıltan 91, Sarıçanak 98, Svevo ve Zenith) kullanılmıştır.

Endüstriyel bir tesiste, eşit proses reçeteleri ve parametreleri kullanılarak bu buğdaylardan makarna ve irmik üretilmiştir. Makarna kalitesini üç ana faktör etkilemektedir: hammadde, üretim reçetesi ve üretim şartları. Bu çalışmada üretim reçeteleri ve şartları sabit tutulmuş olup değişken sadece hammaddir. Böylece makarna kalitesine etki edebilecek üretim reçetesi ve üretim şartlarına bağlı faktörler ortadan kaldırılmıştır.

Üretilen bu makarnaların fiziksel, kimyasal ve duyusal özellikleri belirlenmiştir. Bu yolla, değişik buğday çeşitlerinin makarna kalitesine etkisi araştırılarak, Türk makarna sektörünün iç ve dış pazarlardaki gelişmesine katkı sağlanması amaçlanmıştır.

Makarna kalitesi için en önemli gösterge pişme kalitesidir. Tüketicilerin verdiği bu önem ile pişme kalitesi, buğday ıslahçıları, buğday üreticileri ve kullanıcıları için de önemli bir faktör olmuştur. Yapılan denemeler sonucunda, Svevo, Zenith ve Fırat 93 çeşitlerinden üretilen makarnalar pişme kalitesi olarak diğerleri içinde en iyi sonuçları verirken, Sarıçanak 98, Çeşit 1252, Kızıltan 91 ve Fuatbey 2000'den üretilen makarnaların ise pişme kaliteleri düşük bulunmuştur. Pişme kalitelerindeki bu farkların sebebi, buğday çeşitlerinin sahip olduğu protein miktarı ve protein kalitelerindeki farklardan kaynaklamış olduğu şeklinde yorumlanabilinir.

Makarnadaki açık sarı renk, pişme kalitesi kadar durum buğdayı kalitesi araştırmalarında en önemli göstergelerden bir tanesidir. Yapılan bu çalışmada, Svevo, Burgos ve Zenith çeşitlerinden üretilen makarnaları sarılık değeri diğerlerine göre daha yüksek olup en düşük renk değeri Fırat 93 çeşitinden üretilen makarnada bulunmuştur. Makarnaların sarılık değerlerindeki farkların, buğday çeşitlerinin sahip olduğu farkı miktarlardaki karotenoid pigmentleri, lipoksijenaz ve peroksidaz enzimlerinden kaynaklandığı şeklinde yorumlanabilir.

Anahtar kelimeler : Kalite, Durum Buğdayı, İrmik, Makarna, Çeşit

To My Family

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INTRODUCTION

1.1 General

Pasta is a traditional cereal-based food product that is popular worldwide because of its convenience, palatability, and nutritional quality, especially its low glycemic index (GI) (Petitot et. al., 2008). Pasta quality is evaluated by color, visual appearance and cooking quality. Yellow color (b value), indicating the content of carotenoid pigments, is preferred by consumers for visual appearance. Cooking quality is associated with the quality and quantity of the protein (Kaplan et al., 2008). It is generally recognized that protein content is the primary factor associated with pasta cooking quality, with gluten quality being secondary importance (Feillet and Dexter, 1996).

The main pasta quality aspects, identified by market research and consumer panels, are “*al dente*” trait; low stickiness, yellow color, wholesomeness. These pasta quality parameters are highly correlated with specific durum wheat characters: “al dente”: protein content; low stickiness: protein composition; yellow color: endosperm yellow pigment content; wholesomeness: crop, storage and milling treatments (Ranieri, 1995).

It is obligatory to use durum wheat in pasta and semolina production in Turkey. (Turkish Food Codex, Pasta (2002/20) and semolina regulations (2002/21)).

In Turkey, pasta industry is growing, especially in export markets, rapidly. In domestic and international markets, pasta should have a bright yellow color (also called “amber” color) and should not become sticky when it is cooked but should be “al dente” as indicated by a consumer research carried out by a private research company sponsored by Association of Turkish Pasta Manufacturers (TMSD, 2008)

This thesis is based on TMSD study, stating that, Turkish pasta, when compared to Italian ones, has a pale yellow color and rated a little bit soft and sticky.

Turkish pasta manufacturers have the latest technologies in their mills and pasta plants. So, the only reason for pale yellow color and soft and sticky pasta is the raw material, namely, durum wheat which is processed.

The pasta quality depends on both quality parameters of durum wheat, process parameters of milling and pasta production. In this study, most commonly used 10 durum wheat varieties have been studied to observe the effect of each variety on pasta quality. In this study semolina and pasta from each variety was produced by keeping all the process parameters constant. These parameters include tempering moisture content of wheat, the distance between rollers, the speed differential (ratio between rotating speeds of the rollers), sifting and purifying surfaces, and in pasta production line (mixing, kneading, extrusion, drying parameters), Consequently, it was possible to observe the quality differences coming only from durum wheat varieties.

Durum wheat quality can be comprehended via different meaning by different people: Durum wheat growers may be looking for high yields of attractive look, well filled grains, for the best price. Millers think in terms of wheat that yields the maximum amount of semolina, because the price of semolina is higher than that of by-products such as bran and semolina flour.

Millers also have to meet the semolina specifications demanded by their customers, such as the required protein quantity and quality, color, ash, moisture, etc. Pasta producers, the millers' customers and the last ring of the chain, demand semolina which will result in the high quality pasta that must satisfy the quality expectations of the consumers.

Quality criteria of durum wheat as raw material for pasta manufacturing are continually evolving in response to technological advances in durum wheat milling, pasta making industry, and market pressure and increasing customers' requirements. However, the basic quality criteria valid today, include a high yield of highly refined semolina; high protein and yellow pigment content, strong gluten and good pasta cooking quality, and are to remain valid for the foreseeable future. By means of careful variety selection, optimal combination of environmental conditions and agronomic practices and a good quality evaluation system, durum wheat crop can be obtained at high yield and quality (Hayka, 2009).

Even if this study has been performed by the pasta producers' point of view, the results can be beneficial for all parties in the chain and also for the other researches which will be done for the similar targets.

1.2. Durum Wheat

Durum wheat (*Triticum durum*) is tetraploid wheat a separate species from most other commercially grown wheat classes and it has unique characteristics (Lennox, 2003).

Based on the studies of archeological relics found in various countries of the Middle East, it is assumed that wheat was already being cultivated thousands of years before Christ, first in the "*fertile crescent*" of Palestine and Mesopotamia, later spreading to Western Europe during the Stone Age (Mondelli, 1998).

Over the centuries, following the domestication of wild species and the first breeding attempts, various types of wheat evolved, among which were common wheat (Triticum aestivum L.) and durum wheat (*Triticum turgidum* var. *durum* Desf.). The first type spread mainly to cool/moderate areas, which were fertile and had good rainfalls. Durum wheat, due to its tolerance to droughts and shorter growing cycles (the period between sowing and harvest), grew in adapted to hot/dry climates, such as those of the Mediterranean. Like other living species, durum wheat comes in a number of “varieties” (class of things with common and uniform features, which are different and distinct from others) and its characteristics (yield, adaptability, quality, etc.) can be selected and gradually improved. New varieties can therefore be developed for higher productivity, better resistance to stresses or parasites and/or ability to new cultivation environments (Mondelli, 1998).

Currently, in the world there about 210 million hectares of cultivated wheat, of which 90% is common wheat and 10% is durum wheat. Though durum wheat is cultivated word wide, it is concentrated in specific areas of Asia (India, Kazakhstan, Turkey, Syria and Ukraine), Africa (Algeria, Ethiopia, Morocco and Tunisia), North America (Canada, Mexico and U.S.A.), Australia and Europe (France, Greece, Italy and Spain). On the average, the world produces 35 million tons of durum wheat per year, of which more than 7.9 million tons are produced in EU, 2.9 tons in USA, 3 million tons in Canada and 2.7 million tons in Turkey (TMSD, USDA Commodity Intelligent Report. 22 Dec. 2010).

With some exceptions, durum wheat is a winter crop. In Turkey and Europe, it is generally sown between October and December and harvested at the end of May in the warmer regions and at the end of June or the beginning of July in the cooler regions. In Canada and the northern U.S., the situation is different because of an extremely continental climate, with long, hard winters and short, hot summers. There, wheat is sown in April or May, as soon as temperatures are sufficiently mild, and the harvest takes place at the end of July or the beginning of August.

Pasta quality is determined by three main factors, the raw materials, the production recipe and the production process (Dawe, 2001). In this study, the production recipe and the production process were fixed and only durum wheat varieties were variable. So the effects coming from the production recipe and the production process on pasta quality were eliminated.

The wheat preferred for making pasta products is durum (*Triticum turgidum* var. *durum* Desf.). Durum wheat, in contrast to common wheat *Triticum aestivum* L., which is used to make bread and oriental style noodles, is the hardest wheat and durum milling produces a coarse particle size product, called semolina, ideal for making pasta. The key features of durum wheat include its hardness, intense yellow color and nutty taste. Durum is the best wheat for pasta products due to its excellent amber color and superior cooking quality. Durum wheat with strong gluten characteristics forms strong, non-sticky dough ideal for pasta processing and, in general, tends to produce pasta products with superior cooking characteristics. After conversion to pasta, durum wheat produces products with good cooking quality and stability with unmatchable eating quality (Sissons, 2008).

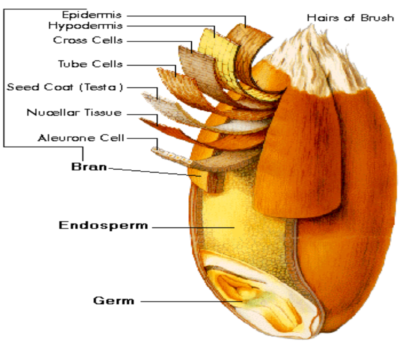

Figure 1 Parts of the wheat kernel (Source: www.classofoods.com)

The most important factor that affects the pasta is quality of the durum wheat that this semolina produced from. In Turkey, durum wheat is mostly used by bulgur, semolina and pasta sectors. Turkey is ranked 5^{th} in the world pasta production and its share in total production is 5.1%. Turkey’s pasta production is 740,684 tons and amount of its pasta export increased up to 295,916 tons (TMSD, 2011).

In Turkey, more than 40 Durum wheat varieties have been cultivated (TMSD, 2011). Especially in the recent years, 10 of the durum varieties representing 80% of total durum wheat production used by pasta manufacturers, which are Amanos 97, Çeşit 1252, Ege 88, Fırat 93, Fuatbey 2000, Burgos, Kızıltan 91, Sarıçanak 98, Svevo and Zenith. In this study, pure and undamaged samples were examined in order to prevent any effects coming from environmental conditions (damages coming from insects, cold, lodging, rusts, mildew, and other diseases).
The cooking quality and color are the two main quality indicators for pasta. Consumers prefer firm and non-sticky pasta when it is cooked. Bright-yellow color is the most preferred color for pasta before and after the cooking.

Numerous scientific researches show that rheological properties of durum wheat is the most important parameter related to cooking quality of pasta (Matsuo et al., 1980; Feillet et al., 1996; Sopiwnyk, 1999; Pena et al., 2002; Ames et al., 2003; Edward et al., 2003; Oak et al., 2006; Wrigley et al., 2006; Aalami, 2006; Aalami et al, 2007; Sissons et all, 2007; Tina Fuad et al., 2010; Sakin et al., 2011) The impact of these components on dough properties and pasta quality has been studied many years. Reports showed that association between glutenin allelic composition and gluten strength in durum wheat (Du Cross, 1987; Pogna et al., 1990; Brites and Carrillo, 2001; Sissons et al., 2005a).

Wheat proteins are a highly heterogeneous material, including albumins (soluble in water), globulins (soluble in neutral salt solution), gliadins (soluble in 70% ethanol and in acids) and glutenins (soluble in acids, bases) (Feillets, 1988). Gluten is a complex mixture of gliadins and glutenins. Gliadins are heterogenous monomeric proteins which are separated into groups on the basis of their mobility on electrophoresis at low pH and responsible for gluten viscosity (Shewry et al., 1999).

Different groups of gliadins, in order of increasing mobility, are the ω- gliadins, γ, β, and α–gliadins (Shewry et al., 1999). The glutenin fraction consists of high molecular weight polymers stabilized by inter-chain disulphate bonds (Carrilo et al., 1990). On the basis of their mobility in SDS-PAGE, the single monomers are usually classified into two groups, the high molecular weight subunits of glutenin (HMW-GS) and the low molecular weight subunits of glutenin (LMW-GS) (Galterio et al., 1991; Gupta et al., 1995; Aalami, 2006). Damidaux et al.(1978) showed that varieties of durum wheat that contain γ-45 gliadin have superior cooking quality than those contain γ-42 gliadin. Both proteins have the same molecular weight (45,000) and similar amino acid composition (Feillet, 1980). On the other hand, Payne et al. (1984) and Pogna et al. (1988) showed that the presence or absence of low molecular weight LMW-1 and LMW-2 glutenins are linked closely genetically to γ-42 and γ-45 gliadins, respectively and these two gliadin polipeptides can be used only as genetic markers for other proteins responsible for gluten quality (Aalami, 2006).

Gluten quantity and composition are the predominant factors associated with superior pasta texture. The protein matrix holds the starch granules during cooking to decrease the loss of solids in the cooking water and thereby reduce the surface stickiness. With very low levels of protein extremely fragile spaghetti is produced with low firmness. High protein durum wheat allows spaghetti swell when cooked (affect mouth feel), reduces cooking loss and allows retention of firmness with overcooking which is also associated with less stickiness (Dexter et al., 1983). Protein content has been noted as a primary factor associated with superior pasta quality (Feillet and Dexter, 1996). D’Egidio et al. (1990) stated that with low temperature pasta drying technology (≤40°C), gluten content and gluten strength assumed to have equal importance in defining pasta quality while for higher temperature drying technology (>70°C), protein content was considered as more important.

The recent scientific researches showed that glutenin/gliadin ratio, amount of HMW-GS (high molecular weight glutenin subunit) or LMW GS (low molecular weight glutenin subunit), γ-Gliadin types (γ-42 or γ-45) have important effects on dough and pasta cooking quality parameters (Edwards et al., 2003; Sissons et al., 2007, Sakin et al., 2011). Among high molecular glutenin subunits, HMW-GS 6+8 or 7+8 give better pasta cooking quality than HMW-GS 20 (Kovacs et al., 1995). Autran and Feillet (1987) showed that a weak but significant relationship between HMW glutenins and pasta quality; HMW-GS 6+8 was positively associated with quality, while 13+16 was negatively associated.

The color of pasta products is mainly influenced by the yellow pigment content and LOX (lipoxygenase) activity of durum wheat (Aalami et al., 2007). For the production of bright yellow pasta products, durum wheats with high pigment content (mainly yellow carotenoids) and low LOX activity are desired. Yellow pigment concentration of the endosperm, due to the presence of xanthophylls and other related compounds (Lepage and Sims, 1968), is an important quality characteristic. Except some special varieties, it is generally accepted that pigment contents of durum wheats fluctuate from 4 to 8 mg/kg (Köksel et al., 2000, Sakin et al., 2010; Sakin et al., 2011).

Color has become more important with increased global competition in pasta marketing. (Dexter and Marchylo, 2001) Yellow pigment concentration (YPC) in durum wheat is an important criterion in the assessment of semolina quality, particularly in determining the commercial and nutritional quality of end-products

(Digesù et al., 2009). Final color is the result of the balance between yellow and brown components in semolina. Carotenoid pigments and lipoxygenase (LOX) enzyme are mainly involved in yellowness, whereas peroxidase (POD) and ash affect brown hue (Borelli et al., 1999; Borelli et al., 2008).

The bright yellow color of durum wheat products is the result of natural carotenoid pigments content and of their oxidative degradation by lipoxygenase activity and depends on several factors, among which intrinsic quality of semolina and processing conditions are considered to be the most important. The phase mainly responsible for pigment loss is the pasta processing, particularly dough mixing, when a substantial decrease in pigment content occurs, highly correlated with semolina LOX activity. Particularly in wheat, the fatty acids radicals produced during the intermediate steps of substrate peroxidation are responsible for oxidative degradation of pigments and of thiol groups of peptides and proteins, so promoting a loss of sulphydryl groups in dough. Thus, these reactions can affect not only the color, but also the rheological properties of wheat dough (Fares et al., 2001).

Carotenoids are important antioxidant compounds that reduce the oxidative damage to biological membranes implied in many human diseases and in the ageing processes. The carotenoid content is one of the main criteria to assess the commercial and nutritional value of pasta products.

1.2.1. Common Wheat and Durum Wheat Difference

Genetics:First of all, common wheat and durum wheat are two different plant "species" (meaning class of things species a similar characteristics that can be interbred to produce fertile seed). Botanically, they both belong to the *Germineae* family, and to the *Triticum* genus, of which numerous wild or cultivated species are a part. The scientific named of durum wheat and common wheat are, respectively, *Triticum turgidum var. durum Desf.* and *Triticum aestivum L.*

From the evolutionary standpoint, it would appear that common wheat derives from an interspecific cross (a cross between different species) between T. *turgidum* and a similar wild graminaceous plant, the *Aegilops squarrosa*, which has provided common wheat with a set of chromosomes that are absent in durum wheat. Thus, the two species present very distinct genetic features, the most evident being the number of chromosomes: 28 in durum wheat and 42 in common wheat.

Morphology:

Morphologically, the two species are similar although they do have numerous differences.

1) Ears of wheat are composed of numerous spikes, which in durum wheat are awned. The awns can grow as high as 7.8 inches and in a full-grown plant they are straw-colored, reddish or black. In common wheat, the ears can be beardless (lacking awns) or awned. In the awned varieties, the awns measure 1.17-3.12 inches and they are more or less divaricated from plant's axis.

2) In common wheat, the last internode of the culm (the portion of the stalk that is nearest to the ear) is empty, while in the durum wheat it is full.

3) There is a fundamental difference in the structure of the grain. In common wheat it has a floury texture when it is fractured while in durum wheat it is glassy.

Consequently, the products obtained from each variety differ greatly. Common wheat produces flour which is white and dusty, and ground durum wheat produces semolina. It has rougher granules and pointed (sharp) particles. The color is yellow amber, its intensity varying depending on the variety.

Although both types are primarily used for human consumption, the technologies employed and the end products are very different. Already in the grinding phase, the production process depends greatly on the characteristics of the caryopsis on the product that one wishes to obtain from it, so that the mill must be configured to suit the raw material.

The varying compositional structure of the proteins is fundamental in determining the typology of product that can be obtained with one or the other raw materials. The dough obtained with common wheat, in fact, is generally very extensible, and of medium/low tenacity, while that obtained with common wheat is generally characterized by high tenacity and minor extensibility. Common wheat is thus particularly suited to the production of bread or leavened products, while durum wheat presents features that are perfectly suited to the production of pasta. Good gluten tenacity permits to keep starch granules inside the pasta structure, reducing stickiness. It also allows the modulation of the absorption of water during cooking, preventing excessive expansion of the pasta, giving it the right firmness (Barilla Alimentare S.p.A.).

1.3. Semolina

Durum wheat milling is different from other classes of wheat milling, in that, there are differences in the wheat, the actual milling processes, final product characteristics and the utilization of those final products (Robinson, 2001). The endosperm of the wheat kernel does not breakdown into fine powdery flour when milled, because the endosperm of durum is hard enough to hold together during milling, and the result is a granular product called semolina, which is used to make spaghetti and other pasta products (Connell et al., 2004).

The term *semolina* derives from the Italian word "semola" that derives from the ancient Latin *simila*, meaning "*flour*," Semolina is the raw material for pasta production and it is a granular product (particles sizes are mostly between 0.125 and 0.450 mm in diameter) obtained from the endosperm of durum wheat by milling and removing bran and germ fractions of the wheat.

Semolina quality requirements vary from country to country (Cubadda, 1988) and the pasta manufacturers have unique requirements for semolina (Dick and Matsuo, 1988). Several main parameters such as moisture content, color, protein quantity and quality, speck counts, granulation are generally considered when describing semolina quality. After the grain is milled into semolina, several criteria are used by pasta makers to assess the pasta quality potential. These include color, speck count, particle size distribution, and protein quality (Sissons, 2004).

The main components of semolina are proteins and starch. Proteins are molecules composed of a sequence of units represented by amino acids. Semolina proteins may be grouped into four principle families, depending on their chemical characteristic and function: albumins, globulins, gliadins, glutenins. From a technological point of view, gliadins and glutenins form gluten which is characterized by fundamental features: By adding water and mechanical energy, these two types of proteins form gluten, which develops a protein matrix that trap the starch. Gluten strength is thought to relate to the balance between viscosity and elasticity (Shewry et al., 2002). It has generally been accepted that semolina from extra strong durum varieties is thought to produce firmer pasta and consequently gluten strength has become sought after in many markets where higher price can be commanded (Marchylo et al., 2001). Kovacs et al. (1997) found stronger significant correlations (r^2 = 0.5-0.8) between mixograph characteristics of dough (a measure of gluten strength) in 12 genotypes grown over three seasons and sensory characteristics of cooked pasta.

Pasta cooking quality has also been described as a competition between starch gelatinization and protein network formation (Dalbon et al, 1982). Thus, it is possible that starch properties also contribute to pasta cooking quality. Although starch represents up to 80% of semolina dry matter (Fortini, 1988) and is the major component of pasta, it has received less attention in research (Lintas and D’Appolina, 1973; Güler et al., 2002; Aalami, 2006).

Starch is a complex molecule composed of long linear or ramified chains of glucose. It accumulates in the endosperm of the durum wheat in the form of granules, in varying sizes and shapes. Starch is fundamental to nutrition as it is the main source of carbohydrates and, therefore, of energy for the organism. Starch is a polymer of α-linked D-glucose residues and is comprised of two types of molecules, amylose and amylopectin. Amylose is a lightly branched polymer, with molecular weight 100,000-1,000,000. In wheat it typically represents about 25% of the starch granules but in some genotypes this can vary greatly from 0-40%.

Amylopectin is a highly branched polymer with MW 10,000,000-100,000,000. The amylose polymer can form complexes with lipids. This amylose-lipid complex resists leaching from the starch granules and also prevents entry of water into the granule. Native starch granules also contain small amounts of proteins, lipids and minerals (Chibbar et al., 2005).

In this study, the semolina samples were produced from all durum varieties under the constant milling conditions in order to prevent any effect which might arise from different milling process. Furthermore, semolina samples were used for spaghetti production as soon as possible after their production in order to eliminate any possible effect (e.g. enzymatic activity) coming from storage time.

The components of durum wheat (protein, gluten, carotenoid pigments and lipoxygenase and peroxidase enzymes), which are indispensible for final product quality, are different across the kernel. The quantities of these key components are higher at the outer surface of the kernel (bran) and germ, but they decrease in the semolina after milling. Thus, analyzing every semolina lot produced from each durum variety helps one to observe the changing trend for these components during milling process for every variety.

1.4. Spaghetti

While for a time it was thought that Marco Polo returned from China with pasta, there are Italian recipe books from twenty years earlier containing reference to pasta dished. The origin of the pasta starts probably with Greeks and “Etruschi”, the word “laganon” was used to point something similar to big tagliatelle. The first certain record of noodles cooked by boiling is in Jerusalem Talmud, written in

Aramic in the 5th century AD. The word used for the noodles was “itriyah”. In Arabic references this word stands for the dried noodles purchased from a vendor, rather than homemade noodles which would have been fresh. Dried noodles are portable while fresh must be eaten immediately. More than likely, pasta was introduced during the Arab conquest of Sicily, carried in as dry stable. The Arab geographer, Al Idrisi wrote that a flour-based product in shape of strings was produced Palermo (Italy), than in Arabic colony.

Second date is 1279, when the Notaio Ugolino Scarpa from Genova write a testament of a man in which in the goods left there were a "bariscela plena de macaronis“ (a container full of Macaroni!). According to an old recipes book wrote by Ibni al Mibrad (IX century), when the Arabs the first to dry pasta to enlarge the shelf life during their migration in the desert.

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At the beginning of the 1900 the production was manual and the drying made in ambient condition using sun and wind.

In 1933 there is the first patent was taken with a machine completely automatic. In 1951 the continuous dryer was born for long pasta with an output of about 200 kg/h and a temperature of 40-45°C. In 1956, the continuous dryer was born for short cuts with an output of 400 kg/h and temperature of 50-55°C. In the 1970’s, it was started developing the high temperature revolution line gets to 1500-2000 kg/h and use temperature up to 70°C. In the 1980’s there was the boost to 80-90°C of temperature and we got to 4000-5000 kg/h. Current situation speaks of 9000 Kg/h with drying cycles of 4-6 hours and Temperature that arrives to 90°C (Barilla Alimentare S.p.A.).

Figure 2 Ambient drying of pasta in the beginning of 1900s. (Drying of pasta in Gragnano in a postcard printed in Naples by E. Ragozino in 1918 Parma, Barilla Historical Archives)

Plain pasta is produced by mixing of durum wheat semolina with water followed by kneading, extrusion, drying processes. As the wet mix of semolina and water passes from the mixer into the vacuum screw of the extruder, it is formed into dough by application of mechanical work (Dawe, 2001). The dough is characterized by the formation of a gluten network where the semolina granules which contain protein exude fibrils, which interact to form cohesive dough (Amend and Belits, 1989).

Overall quality of durum wheat pasta is influenced primarily by the properties of the protein and the starch fraction, and their transformation during extrusion, drying, and cooking (Zweifel et al., 2000). The resultant wet pasta has a network of protein that envelops the starch granules to make a structure that has free of cracks and voids.

Figure 3 Latest technology pasta production line (Source: FAVA)

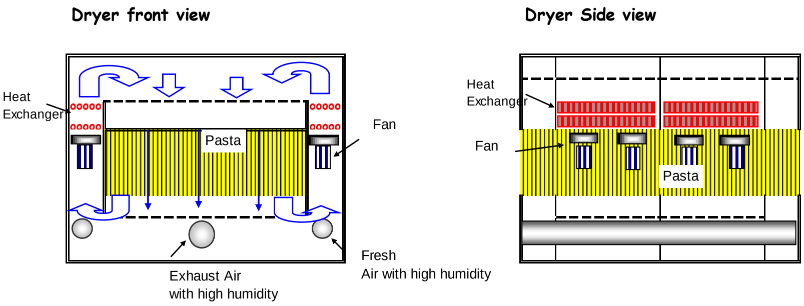

Figure 4 Drying process of pasta (Source: Barilla)

In the semolina the gluten is glassy but upon the addition of some water it becomes rubbery and elastic, acquiring the ability to form strand and sheets via inter-molecular bonds. This matrix helps to trap the starch granules in pasta and hold its shape during cooking. When the hydrated gluten is heated, irreversible protein-protein cross-links are formed. The starch behaves like inert filler below 55 °C and cannot absorb much water (Sisson, 2008).

After shaping in moulds, drying process starts which have certain process parameters (temperature, relative humidity, etc.). At the end of the drying and stabilization processes, dough turns to elastic stage from plastic stage and pasta is obtained.

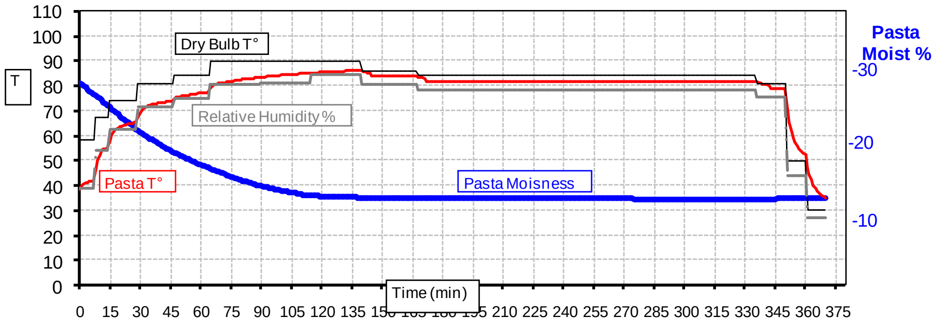

Figure 5 Drying cycle of spaghetti (source: Barilla)

Spaghetti is the most popular one in the pasta shapes. In traditional pasta-consuming countries the consumer is concerned about the aroma, color, appearance, texture, flavor and nutritional value of the pasta.

D'Egidio and Nardi (1998) stated that the cooking quality and color are the most important parameters for pasta quality. Pasta made from durum wheat cultivars of superior quality results in a bright yellow color and it retains firm and non-sticky structure even after cooking.

1.4.1. Cooking Quality

The important test of acceptability of pasta products is its cooking quality (Matsuo, 1988). Cooking quality of pasta products is of importance to consumers and thereby to wheat producers, breeders and manufacturers (Felliet and Dexter, 1998). Proper evaluation of pasta cooking quality requires consideration of a number of factors including its elasticity, firmness, stickiness, cooking time, water absorption, and loss of solids to cooking water (Edwards et al., 1993; Feillet, 1984).

After cooking, the pasta products should maintain its texture and not become a thick sticky mass. The process conditions and composition of raw material play the main role for the cooking quality of pasta. The type of proteins present in the grain affects processing properties. Group of proteins in wheat, which exert the most influence on the strength and elastic properties of dough, are the glutenin and gliadins. The polypeptide complex composed of glutenin, gliadin and lipid is defined as the visco-elastic mass remaining after removal of the starch (Miflin et al., 1983; Sissons 2008).

The protein matrix holds the starch granules during cooking to decrease the loss of solids in the cooking water and thereby reduces surface stickiness. Insufficient levels of protein lead to formation of extremely fragile spaghetti with low firmness. High protein durum wheat reduces cooking loss and allows retention of firmness with overcooking which is also associated with desired non-sticky surface (Dexter et al., 1983).

Gluten quality (strength) is a term used to describe the ability of the protein to form a satisfactory network that promotes good cooking quality. In pasta, gluten must be tenacious enough to retain the gelatinized starch granules during cooking. The continuity and strength of the protein matrix formed during dough mixing and extrusion is important in defining the textural characteristics of the pasta. Compared to weak gluten of same protein level, strong gluten wheat exhibit less sticky dough with better extrusion properties and superior cooked textural characteristics (Dexter and Matsuo, 1978; Autran et al.; D'Egidio et al.; 1993; Sissons et al.; 2005).

Sensory evaluation is the commonly used method for testing cooking quality of pasta. The sensory judgment of firmness and the overall sensory judgment are significantly correlated with gluten content ($P<0.01$ and $P< 0.001$), respectively (Pasqualone et al., 2008). In this method, bulkiness, stickiness, and firmness of pasta samples can be tested and compared with those of reference samples.

1.4.2. Color

Bright yellow color of pasta is an important quality parameter for the consumers. The desired characteristic color is the result of many parameters such as;

- the natural carotenoid pigments present in the kernel,
- their residual content after milling and after the storage of either grain or semolina,
- their oxidative degradation by lipoxygenase (LOX) during pasta processing,
- the oxidative balance among different compounds implied in this reaction,
- the process conditions

Final color is the result of the balance between yellow and brown components in product. Carotenoid pigments and lipoxygenase (LOX) enzyme are mainly involved in yellowness, whereas peroxidase (POD) and ash affect brown hue (Borelli et al., 2008).

The bright yellow color of pasta products, rather than cooking behavior taste, is reported to be one of the most important considerations in assessing durum wheat quality (Borelli et al., 1999). Yellow pasta is considered a mark of quality by many consumers (Dexter et al., 1981). However, a high level of yellow pigments in durum wheat and semolina does not guarantee a high yellowness in pasta, because pasta yellowness and pigment loss during processing are mainly affected by enzymes such as lipoxygenase (LOX), peroxidase (POD), and polyphenol oxidase (PPO) activities (Aalami, 2006).

The instrumental methods for measuring the color of cereal and cereal products are used: (i) extraction of carotenoids and xanthopyll pigments and measurements of them using transmitted-light colorimetry; (ii) direct measurement of the yellow index (b) using reflected-light colorimetry (Landi, 1995).

In this study the yellowness of the wheat varieties and semolina and spaghetti produced from each variety were measured and compared with each other.

CHAPTER 2

MATERIALS AND METHODS

2.1. Materials

The main durum wheat varieties those represent about 80 % durum wheat crop in Turkey in 2009 (source: TMSD) have been used in this study. The following pure durum wheat varieties were obtained from Central and Southeastern Anatolia regions:

Table 1 Durum wheat genotypes used in the study.

Number	Genotype	Breeding Institution
1	Amanos-97	Çukurova Agricultural Research Institute
2	Burgos	Spain
3	Çeşit-1252	Field Crops Central Research Institute
4	Ege-88	Aegean Agricultural Research Institute
5	Fırat-93	Southeast Agricultural Research Institute
6	Fuatbey-2000	Çukurova Agricultural Research Institute
7	Kızıltan-91	Field Crops Central Research Institute
8	Sarıçanak-98	Southeast Agricultural Research Institute
9	Svevo	Barilla S.p.A. and PSB (Italy)
10	Zenith	Barilla S.p.A. and PSB (Italy)

Semolina samples have been obtained by milling of durum wheat varieties in an industrial semolina mill (Barilla Gıda Bolu Mill). Because the different milling conditions may affect the quality parameters of semolina, (Dexter et al., 2004) the same milling conditions (semolina extraction rates, tempering moisture content, the distances between rollers, the ratio between rotating speeds of the rollers, sifting and purifying surfaces, etc.) were applied to all of the samples.

Spaghetti samples with 1.7 mm diameter have been produced in an industrial pasta production line (Barilla Gıda Bolu Plant, Long Cut Production Line, Braibanti) applying same pasta production recipe and process conditions. (The Technological Standard Sheet is given in Appendix-1)

2.2. Methods

2.2.1. Semolina Productions

By using each pure durum wheat variety, 10 semolina lots have been produced in the Barilla Gıda Bolu Mill applying the same milling diagram and milling conditions:

The following conditions were applied to all of the samples:

- Tempering time: 4 hours in initial tempering + 4 hours in final tempering,
- Tempering moisture: 17.3% ± 0.1%,
- Constant roller-mills working parameters (gaps in rollers, break-roll differentials, positions of rollers, air-pressure, rotational speed, etc.),
- Constant sifter working parameters (sieves, rotational speed, sifting surface, etc...,),
- Constant purifying conditions (sieves, rotational speed, purifying surface, air pressure of the purifiers),

- Constant semolina extraction rate at 70%.

2.2.2. Spaghetti Productions

10 different spaghetti samples, having 1.7 mm diameter and 25.5 cm length, have been produced from 10 different semolina lots extracted from 10 different durum wheat varieties which were subject of this study. Same pasta production parameters and conditions were applied in all cases. (The Technological Standard Sheet is given in Appendix-1)

2.2.3. Test weight

AACC 55-10.01 (2000) method was applied to all durum wheat varieties using the "Hectoliter Measurement" instrument.

2.2.4. Kernel vitreousness

The term vitreousness applies to the proportion by weight of vitreous durum wheat kernels in 100 g of a sample as prepared for "Besatz"-analysis according to ICC Standard No. 102/1 (Approved: 1964, Revised: 1972) and vitreousness % has been defined according to ICC Standard no. 129 (Approved: 1980). (Method for determination of the vitreousness of durum wheat)

2.2.5. **Protein Quantity**

Protein quantity analysis was done according to standard method (Method: AACC 46-10.01, 2000) using conversion factor of 5.7 and using the BÜCHI Auto-Kjeldahl Unit K-370 (Switzerland).

Figure 6 BÜCHI Auto-Kjeldahl Unit K-370

2.2.6. **Gluten Quantity and Quality**

Gluten quantity analyses were done according to standard method (ICC Standard No. 137/1: Mechanical determination of the gluten content of wheat flour) by using a Perten Glutomatic 2200 –Gluten Index-(ICC) (Sweden-1999).

Glutograph: The procedure was carried out for all samples according to the Manual of the manufacturer (Brabender GmbH and Co. Duisburg, Germany) of the glutograph-1752E for determination of gluten quality.
Analyses were applied on wheat and semolina samples according to method given in Appendix 2.

Figure 7 Perten Glutomatic 2200 – Gluten Index-(ICC)

Figure 8 Brabender Glutograph 86049

2.2.7. **Color**

The color of all samples was measured by light reflectance using the colorimeters (model, CR300 for wheat and semolina, model CR410 for spaghetti, Minolta Corp.,) by the method given in Appendix 4 which depends on AACC Method 14-22, 1983.

AACC Method 14-22, 1983, light reflectance Model CR-300 and Minolta CR-410, (Minolta CR-300 Colorimeter has been used to measure the color indices (L*, a* and b*) of wheat and semolina samples and Minolta CR-410 has been used to measure the color indices of spaghetti samples) Minolta Camera C., Japan were used.

L* is a measure of brightness.

a* indicates red-green chromacity. Positive values indicate increased redness.

b* indicates yellow-blue chromacity. Positive values indicate increased yellowness

2.2.8. Cooking Quality

Cooking quality of spaghetti samples were analyzed by a group of trained panelists at Quality and Technology Section of Barilla Turkey, Bolu, Turkey). The sensory cooking quality parameters of all samples were measured by the method given in Appendix 3.

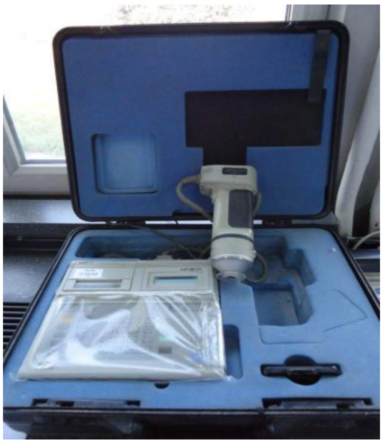

Figure 9 Minolta CR-300 Colorimeter

Figure 10 Minolta CR-410 Colorimeter

Samples were cooked and they were compared with each other and with reference samples for their following characteristics (Source: Barilla)

Bulkiness: The ability of one piece of cooked pasta to slide smoothly against another.

Stickiness: State of surface breakage of the cooked pasta with release of finger.
Firmness: Resistance of the cooked pasta to squashing between the fingers.

2.2.9. Cooking Loss

The method defined in the TS 1620 Pasta Standard (TSE, 1976) is applied to measure cooking loss analyses for spaghetti samples.
The cooking loss of all spaghetti samples was measured by the method defined in the Pasta Standard which was published by TSE (TS-1620).

CHAPTER 3

RESULTS AND DISCUSSION

3.1. Test Weight and Vitreousness of Wheat Samples

By using the "Hectoliter" instrument, the test weights of all durum wheat varieties have been measures as a unit of Kg/HL. As shown in Table 2 the test weight of durum wheat varieties are ranged between 77 Kg/HL (Kızıltan 91) and 81 Kg/HL (Svevo).

The vitreousness of durum wheat samples were between 72% (Kızıltan 91) and 94% (Svevo) as shown in Table 2.

3.2. Color

The yellowness index (b indices) of durum wheat varieties and those of semolina and spaghetti products, which were produced from these varieties, are given in Table 3. The highest scores for spaghetti belong to the samples produced from Svevo (indices b = 46.03), Burgos (indices b= 45.26) and Zenith (indices b= 44.43) varieties. These results are not unexpected because the yellow colors of wheat and semolina for these varieties are higher than the others: Indices b values are 23.03, 23.36, and 21.96 for Svevo, Burgos and Zenith varieties, respectively. These results are in agreement with the previous findings (Coşkun et al., 2010) where six durum wheat varieties (Zenith, Svevo, Alibaba, Sarıçanak-98, Fuatbey-2000, Akçakale-2000) had been examined for their yellow color and it was stated that Zenith and

Svevo varieties had higher quality than others. Also Sakin et.al (2011) stated that Zenith is one of the genotypes prevailed in pasta color quality associated characteristics with other 3 variety among 25 durum wheat genotypes which were subject in their study.

Table 2 Vitreousness and Test Weights of Wheat Samples (n=10)

Raw Material Variety	Vitreous Kernel (%)	Test Weight (Kg/HL)
Svevo	94	81
Sarıçanak 98	82	79
Amanos 97	87	80
Burgos	88	80
Fuatbey 2000	76	79
Ç-1252	76	78
Kızıltan 91	72	77
Firat 93	85	79
Ege 88	75	80
Zenith	83	79

The spaghetti samples produced from varieties Ç-1252, Ege 88, and Fırat 93 have low yellowness scores. The yellowness indexes of these wheat varieties are also low. Considering the color scores of both the durum wheat varieties and the spaghetti samples produced from these varieties, one can interpret that durum wheat varieties which have high yellowness scores lead to the high yellowness score for pasta. The correlation was also proved by several scientific researches (Ranieri, 1995; Taha et al, 1987; Abecassis et al, 2001; Borelli et al, 2008).

Table 3 Yellowness (indices b) of wheat, semolina and spaghetti samples (n=10)

Variety	Indice b (Wheat)	Indice b (Semolina)	Indice b (Spaghetti)
Svevo	23,03	25,73	46,03
Saricanak 98	21,27	22,5	42,24
Amanos 97	20,99	22,95	42,90
Burgos	23,36	25,48	45,26
Fuatbey 2000	19,22	21,25	42,10
Ç-1252	18,80	20,74	41,62
Kızıltan 91	21,12	23,83	42,23
Firat 93	17,93	20,04	40,71
Ege 88	19,42	21,47	41,68
Zenith	21,96	24,70	44,43

Also the relation between the color of wheat and colors of semolina and spaghetti were examined. As it is shown in Figures 11, 12, 13, there are significant correlations between them.

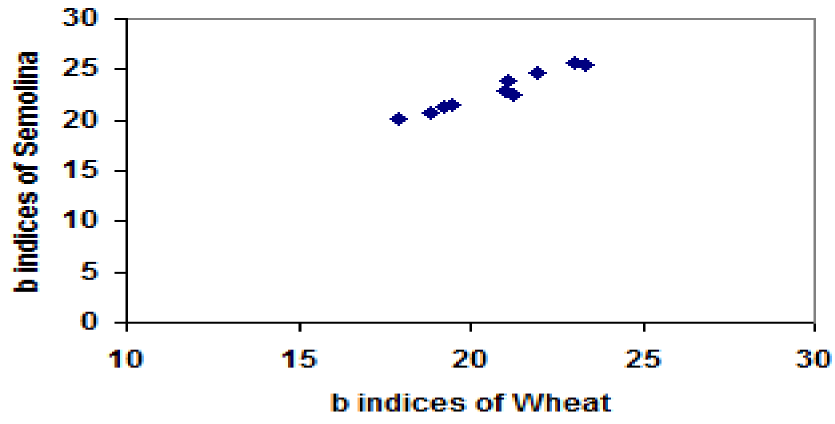

Figure 11 Yellowness of wheat (indices b) versus yellowness of semolina (r = 0.976)

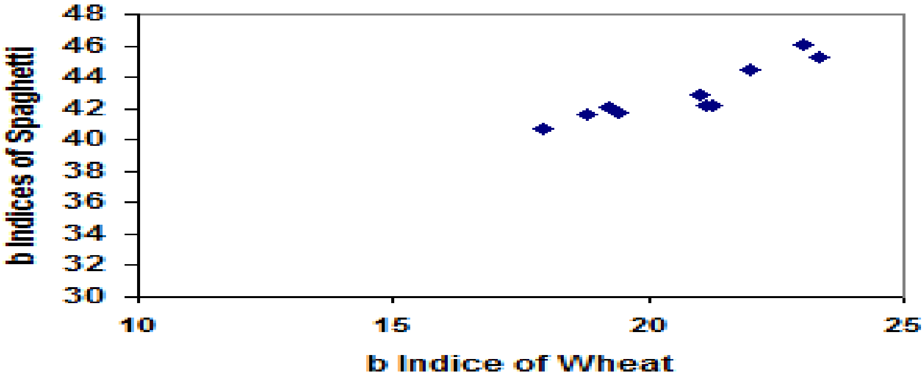

Figure 12 Yellowness of wheat (indices b) versus yellowness of spaghetti (r= 0.917)

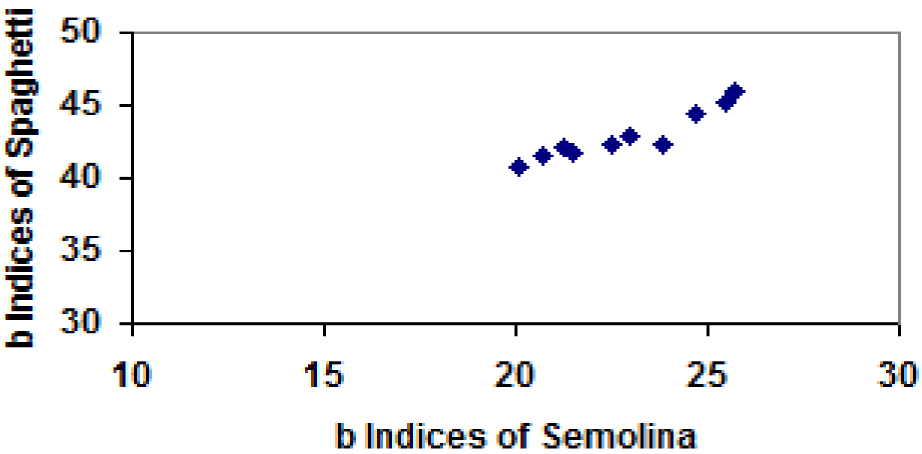

Figure 13 Yellowness of semolina (indices b) versus yellowness of spaghetti (r= 0.935)

3.3. Protein Quantity

The protein contents of durum wheat and spaghetti samples are given in Table 4. Fırat 93 and Svevo varieties have higher protein contents comparing to others. The protein

content of the variety Ege 88 is quite low. It must be noted that the protein contents of wheat may differ by both genotype and environment (Nachit et al., 1995; Bushuk 1998; Troccelli et al., 2000; Sakin et al., 2011). Further studies can be done by using same varieties under different environmental conditions.

Table 4 also shows that spaghetti sample produced from Svevo variety has the highest protein content (13.56% Nx5.7 d.m.). The spaghetti sample produced from Zenith variety ranked 2nd (12.96%), the sample produced from Fırat 93 ranked 3rd, and the sample produced from Ege 88 have the lowest amount of protein.

3.4. Gluten Quantity and Quality

Durum wheat breeding programs generally focus on quality factors associated with pasta. Gluten quantity and the composition are predominant factors associated with superior pasta texture.

In this study, the gluten quantity and quality of all durum wheat varieties, semolina products, and spaghetti samples were measured by instruments and methods explained in Appendix 2.

Table 4 Protein contents of wheat and spaghetti samples. (Nx5.7 d.m.)

Variety	**Protein (Wheat)**	**Protein (Spaghetti)**
Svevo	14.41	13.56
Sarıçanak 98	12.77	11.85
Amanos 97	13.02	12.47
Burgos	12.98	12.47
Fuatbey 2000	12.33	11.77
Ç-1252	12.75	12.00
Kızıltan 91	12.91	12.27
Fırat 93	14.55	12.94
Ege 88	11.75	10.67
Zenith	13.89	12.96

Svevo, Fırat 93 and Zenith varieties have higher dry gluten quantity. Also these three varieties have higher scores in gluten quality comparing to other varieties.

The semolina samples which produced from these durum varieties were analyzed to define their gluten quantity and quality. The following scores have been obtained.

Semolina samples produced from Svevo, Fırat 93 and Zenith varieties have higher gluten quantity comparing to others. Also these three semolina samples have higher scores in gluten quality. Especially the samples produced from Svevo and Zenith have very high scores. The semolina samples produced from Sarıçanak 98, Ç-1252 and Kızıltan 91 have low scores for gluten quality.

Table 5 Gluten quantities and qualities of durum wheat varieties

Variety	Gluten Quantity (%)	Gluten Quality
Svevo	11.9	5.9
Sarıçanak 98	9.7	4.0
Amanos 97	9.9	4.1
Burgos	10.4	5.1
Fuatbey 2000	10.1	4.5
Ç-1252	9.8	4.3
Kızıltan 91	10.5	4.4
Fırat 93	11.6	5.3
Ege 88	9.4	5.0
Zenith	10.9	5.8

When we compared the gluten quantities of wheat and semolina, we observe gluten quantity decreases from wheat to semolina for all varieties. (Figure 14) This is an indicator that a gluten fraction of bran is more than those of endosperm of the wheat.

When we compare the gluten quality of durum wheat varieties with the semolina samples produced from these varieties, we observe that, except Svevo and Zenith, for all varieties the score decreases from wheat to semolina (Figure 15). This can be an indicator that gluten fractions which give strength to gluten are more in bran part of wheat comparing those in endosperm for these varieties. About Svevo and Zenith varieties, we can say that the gluten fractions which give strength to gluten are homogenous, even more in endosperm, in the bran and endosperm parts of these varieties.

Table 6 Gluten quantities and qualities of semolina samples which have been produced from durum wheat varieties (n=10)

Variety	**Gluten Quantity (%)**	**Gluten Quality**
Svevo	11.2	6.2
Sarıçanak 98	9.3	3.6
Amanos 97	9.6	4.0
Burgos	9.9	4.9
Fuatbey 2000	9.2	4.0
Ç-1252	8.8	3.8
Kızıltan 91	10.2	3.9
Firat 93	11.2	5.1
Ege 88	9.1	4.4
Zenith	10.4	5.9

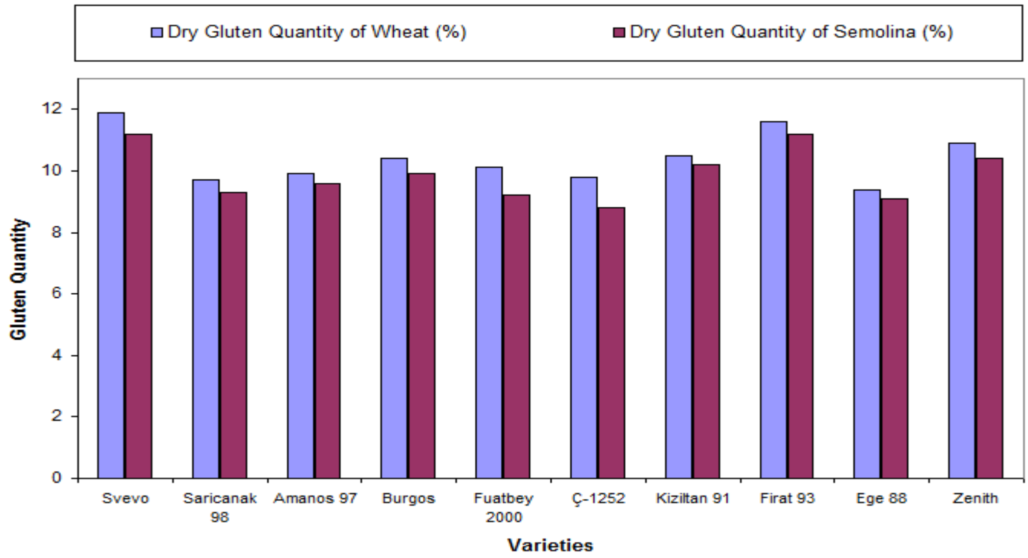

Figure 14 Gluten quantities of wheat and semolina samples

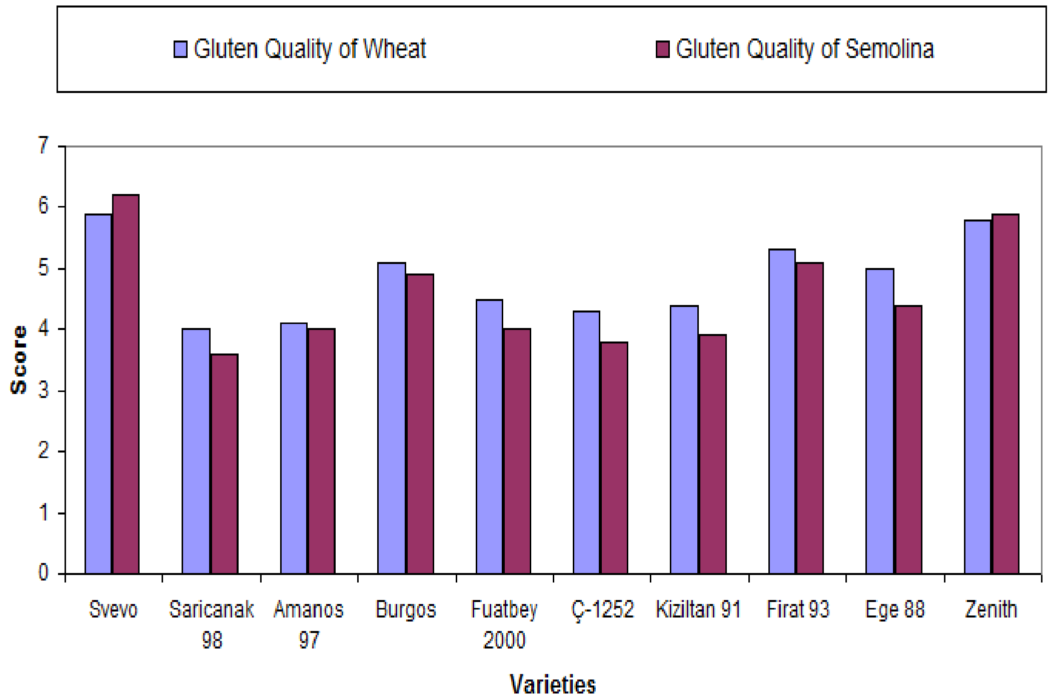

Figure 15 Gluten qualities of wheat and semolina samples

3.5. Cooking Qualities of Spaghetti Samples

10 spaghetti samples which were produced from 10 durum wheat varieties were tested for their cooking quality characteristics (bulkiness, stickiness, firmness) according to method given in Appendix 3. The results are given in Table 7. Less bulkiness, less stickiness and high firmness get higher scores.

Table 7 Cooking Quality Scores of Spaghetti Samples

Raw Material Variety	Bulkiness	Stickiness	Firmness
Svevo	70	75	75
Sarıçanak 98	60	55	60
Amanos 97	60	55	65
Burgos	65	60	65
Fuatbey 2000	60	60	60
Ç-1252	60	55	60
Kızıltan 91	60	60	60
Fırat 93	65	70	70
Ege 88	65	60	65
Zenith	70	70	75

When we consider the bulkiness (the ability of one piece of pasta to slide against another) the spaghetti samples which were produced from Svevo and Zenith varieties get the highest scores as 70. The samples produced from the varieties of Burgos and Fırat 91.

93 and Ege 88 get the medium scores (65) and the spaghetti samples produced from other varieties get the minimum scores. (60)

The other cooking quality factor is stickiness which is defined as the state of surface breakage of the cooked pasta, with release of finger. The more stickiness gets low score. The spaghetti sample which was produced from Svevo variety gets the highest score (75). The samples produced from Fırat 93 and Zenith get the second rank with the score of 70. The samples produced from Sarıçanak 98, Ç-1252 and Amanos 97 were evaluated as a poor quality with the score of 55. In the firmness test which indicates the resistance of the cooked pasta, the spaghetti samples produced from Svevo and Zenith varieties get the highest score (75). The sample produced from Fırat 93 follows them with the score of 70. The spaghetti samples produced from Sarıçanak 98, Fuatbey 2000, Ç-1252 and Kızıltan varieties get the lowest scores (60).

The results show that the durum varieties and semolina having higher protein and gluten quantity and higher gluten quality give higher cooking quality in spaghetti samples. This agrees with the results of previous scientific studies (D'Egidio et al., 1979; Dexter et al., 1983; D'Egidio et al., 1993; Aalami, 2006). When we compare the gluten quality scores of semolina and cooking quality parameters of spaghetti, we observed that there are significant correlations. (Figures 16, 17, 18)

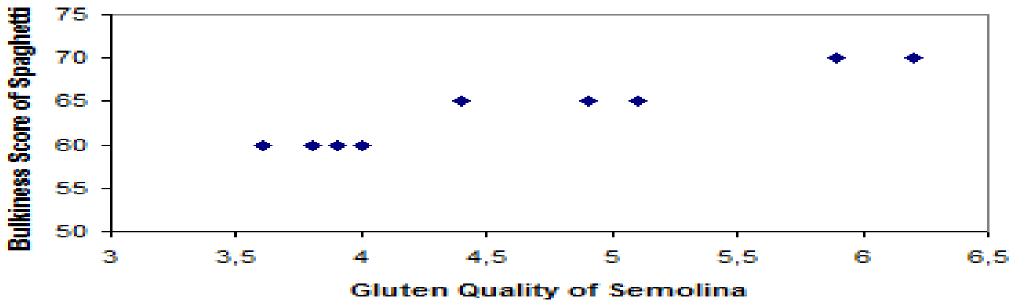

Figure 16 Gluten qualities of semolina versus bulkiness scores of spaghetti (r= 0. 968)

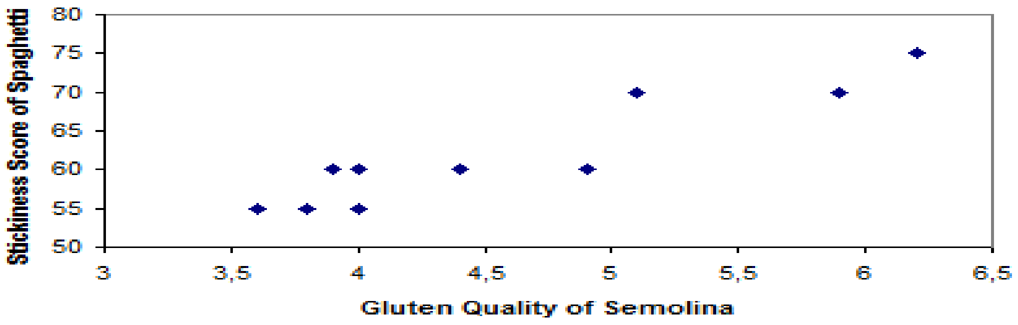

Figure 17 Gluten qualities of semolina versus stickiness scores of spaghetti (r=0.927)

Figure 18 Gluten qualities of semolina versus firmness scores of spaghetti

3.6. Cooking Loss of Spaghetti Samples

Cooking loss measures the amount of solid materials lost in the cooking water which is not wanted by consumers. Cooking loss values of the spaghetti samples are given in Table 8.

Higher score for cooking loss is an indicator for weak protein network which cannot retain starches molecules during cooking and can cause stickiness of spaghetti.

Table 8 Cooking loss of spaghetti samples (n=10)

Variety	**Cooking Loss of Spaghetti (%)**
Svevo	4.2
Sarıçanak 98	8.8
Amanos 97	8.2
Burgos	7.5
Fuatbey 2000	7.9
Ç-1252	9.2
Kızıltan 91	7.4
Fırat 93	5.3
Ege 88	7.6
Zenith	4.1

As it is shown in Table 8, the cooking loss scores rank from 4.1% to 9.2%. The spaghetti produced from Zenith and Svevo have minimum cooking loss, 4.1 and

4.2% respectively. The cooking loss results for samples produced from Ç-1252 and Sarıçanak varieties are extremely high. (9.2% for Sarıçanak and 8.8% for Ç-1252) Even if protein contents of spaghetti samples produced from Sarıçanak and Ç-1252 varieties do not have the worst scores, they get the worst score for cooking loss. In discussions parts of gluten quality and quantity sections, we observed that gluten quantity and quality scores of semolina produced from Saricanak and Ç-1252 varieties were relatively lower than those of other varieties. This situation can be considered as a main reason of low quality for cooking loss for these varieties.

Also it was observed that there was a relation between cooking loss of pasta and gluten quantity and quality: Increasing gluten quality and quantity decreases the cooking loss. (Figure 19 and Figure 20)

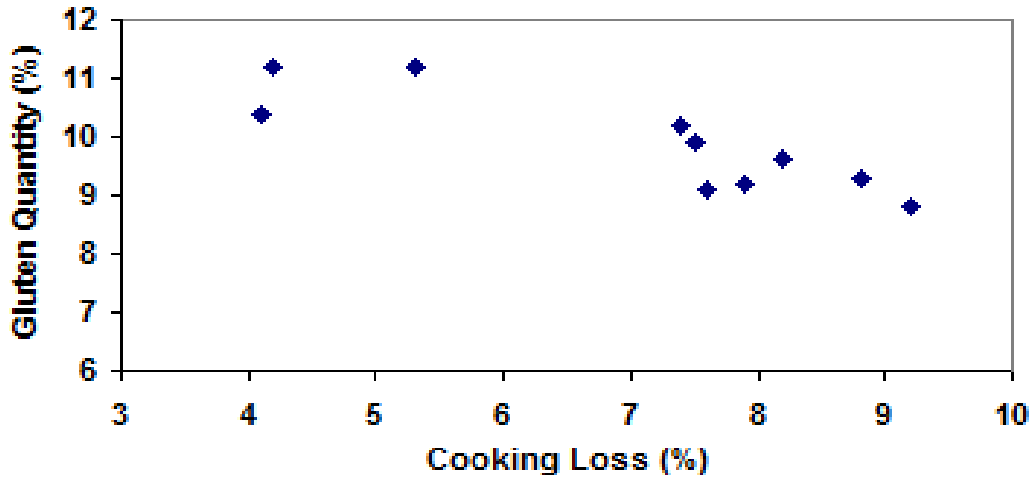

Figure 19 Gluten quantities of semolina versus cooking loss of spaghetti (r=-0.866).

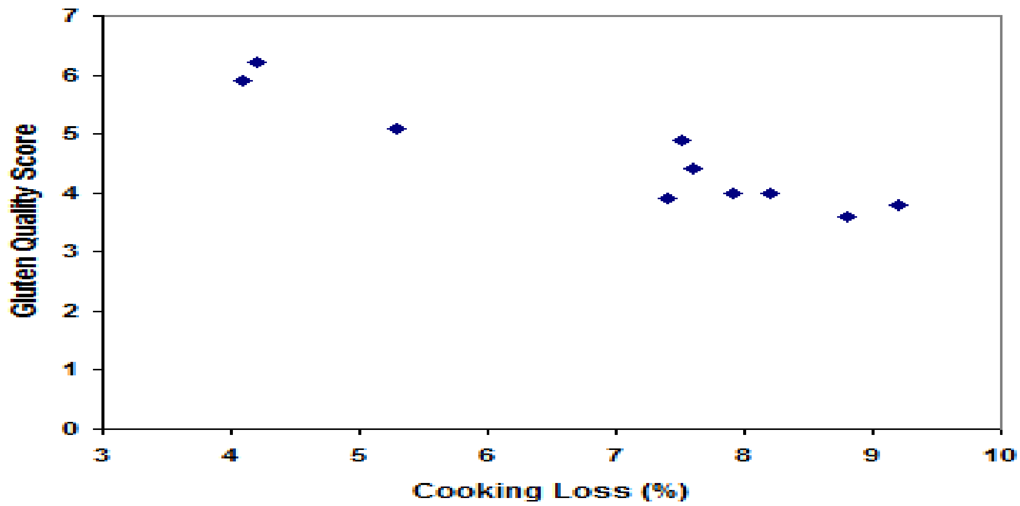

Figure 20 Gluten quality of semolina versus cooking loss of spaghetti (r=- 0.942).

3.7. Evaluation of Spaghetti Samples for Each Variety

3.7.1. Svevo

The spaghetti sample which was produced from Svevo variety gets the highest scores for almost all quality parameters and it can be ranked at the first place according to general quality parameters (Cooking quality and color). This variety was developed through pedigree breeding of Zenith and Linea varieties. Svevo variety is recognized with high yellow index, very high protein content, good gluten quality and good resistances to powdery mildew, brown rust, cold and medium resistance to lodging (PSB-Societa Produttori Sementi S.p.A. Bologna, 2008).

In this study Svevo has the highest scores in yellowness (indices b= 46.03) and in cooking quality parameters (bulkiness= 70, stickiness= 75, firmness= 75).

Also it has the highest protein quantity (13.56%) among other spaghetti samples. For cooking loss, it was ranked to 2nd place, with 4.2% loss; just behind the spaghetti sample produced from Zenith variety which has 4.1% cooking loss.

Figure 21 Cooked and uncooked spaghetti produced from Svevo variety.

We can attribute these highest scores for pasta sample to the superior quality parameters of wheat of which vitreousness is 94%, TW is 81 Kg/HL, color b-indices is 23.03, protein content is 14.41%, gluten content is 11,9%, and gluten quality is 5.9. The highest scores obtained from Svevo variety confirms the results of Simeone et al. (2001) in which it was declared after several years of experimentation that Flamino and Svevo were the most suitable for pasta making among the durum wheat varieties examined.

3.7.2. Zenith

The spaghetti produced from Zenith variety is ranked at 2nd place for the general quality parameters just behind the spaghetti produced from Svevo variety.

Figure 22 Cooked and uncooked spaghetti produced from Zenith variety.

It gets 3rd highest scores in yellowness (indices b= 44.43), 2nd highest scores in cooking quality parameters (bulkiness= 70, stickiness = 70, firmness= 75). Also it has the second highest protein quantity with 12.96%. For cooking loss, it was ranked at 1st place, with 4.1% loss which is minimum lost among all samples.

The good scores obtained from Zenith variety in this study confirm the similar studies performed before (Coşkun et al., 2010; Sakin et al., 2011).

3.7.3. Fırat 93

Fırat 93 genotype was bred by Southeast Agricultural Research Institute and is grown generally 1st and 2nd sub-regions. (Diyarbakır, Şanlıurfa, Mardin, Gaziantep, Adıyaman, Siirt, Batman)

Considering testing results for the cooking quality parameters, the spaghetti sample produced from Fırat 93 variety can be ranked at 3rd place (bulkiness= 65, stickiness = 70, firmness= 70). The cooking loss is 5.3% which makes it to get to 3rd just behind the samples produced from Zenith and Svevo varieties. The high protein and gluten quantities and qualities of the variety may lead to these good results in cooking quality parameters.

Considering coloring tests which shows the yellowness of the samples as “b indices”, the sample produced this variety gets the lowest value as 40.71. This low yellowness value of spaghetti comes from the low yellowness (indices b) of the wheat which was measured as 17.93

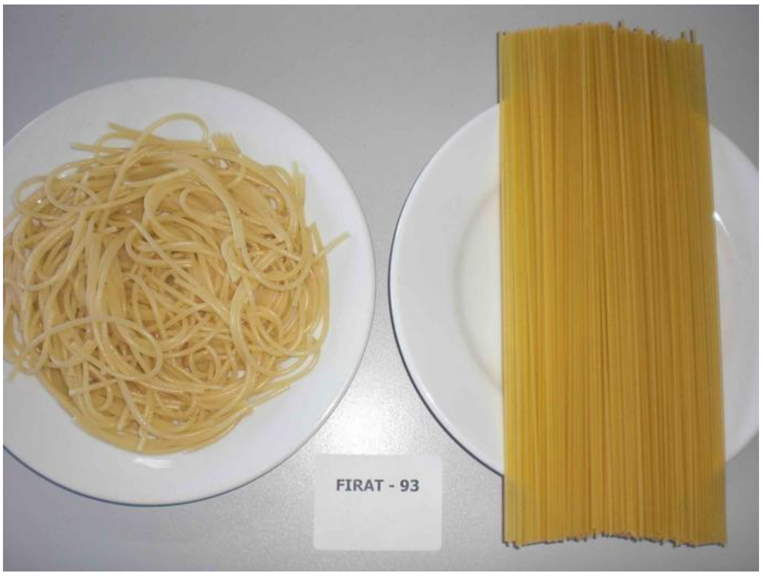

Figure 23 Cooked and uncooked spaghetti produced from Firat-93 variety

Another remarkable point for this variety is the difference between protein quantities of wheat and spaghetti. The protein content of wheat was 14.55 % (Nx5.70 d.m.) but after milling to obtain semolina, the protein content decreased to 12.94 % which means 11% reduction. This difference may show that the amino acid content in bran part is more than that of in endosperm part.

Interbreeding of this variety with a variety which has high yellow index may be resulted a new variety with higher values for both cooking and color results.

3.7.4. Burgos

The yellowness of wheat was very high (indices b = 23.36) for this variety so the spaghetti sample produced from Burgos variety gets the 2nd rank in color evaluation with its "b indices" of 45.26 among all samples.
The cooking quality parameters of the spaghetti sample were evaluated as medium values (bulkiness = 65, stickiness = 60, firmness= 65).

Figure 24 Cooked and uncooked spaghetti produced from Burgos variety

3.7.5. Ege 88

Ege 88 durum wheat variety was bred by Aegean Agricultural Research Institute by the pedigree of JORI/ANHINGA//FLAMINGO (BITTEREN//”S”) cm 9799-126M-1M-4Y-0M~~.~~ Southeastern Anatolia and the Coastal Regions are recommended for cultivation of this variety. Ege 88 durum wheat variety is known as its good resistance to wheat smut and medium resistance to black-colored smut, leaf rust, stem rust and stripe rust.

Even if the protein and gluten quantities were lowest, the cooking quality parameters of the spaghetti sample produced from this variety gets the same values with those produced from Burgos (bulkiness = 65, stickiness = 60, firmness= 65). But, the gluten quality was relatively high (4.4) so, this score for gluten quality may increase the cooking quality parameters to medium levels.

Figure 25 Cooked and uncooked spaghetti produced from Ege 88 variety

The yellowness index of the spaghetti gets 8th place with 41.68 which is an acceptable value for spaghetti.

3.7.6. Kızıltan 91

Figure 26 Cooked and uncooked spaghetti produced from Kızıltan 91 variety

This variety was bred by Field Crops Central Research Institute. Its pedigree is ÜVY162/61 -130 and BY2E/TC. It is generally cultivated in Central Anatolia and transition regions. Kızıltan 91 durum wheat variety is known as its tolerance against wheat smut, black-colored smut and stripe rust and its medium resistance to leaf rust.

The spaghetti sample produced from Kızıltan 91 variety gets 6th rank among all samples for both cooking quality and color parameters. All three cooking quality parameters were evaluated as 60.

The yellow b index was measured as 42.23. Even if it ranks at 6th place for color, this value is accepted as good color for spaghetti products by pasta producers.

3.7.7. Fuatbey 2000

This variety was bred by Çukurova Agricultural Research Institute and it has good resistance to stripe rust and septoria and medium resistance to leaf rust. Its resistances to cold and drought are good and medium, respectively. The spaghetti sample produced from Fuatbey 2000 get the same scores about cooking quality parameters with the sample produced from Kızıltan 91 variety (bulkiness = 60, stickiness = 60, firmness= 60). Also the yellowness of the sample has very similar score with the same sample: The color b index is 42.10

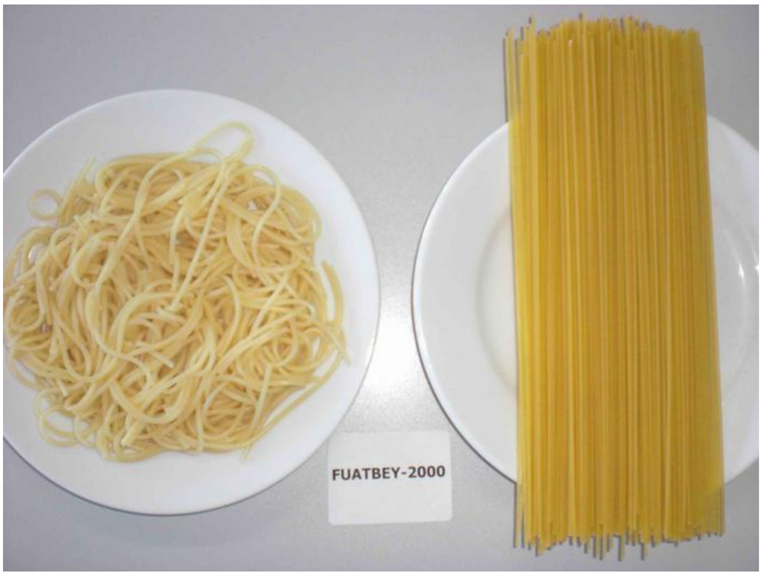

Figure 27 Cooked and uncooked spaghetti produced from Fuatbey variety

3.7.8. Amanos 97

Like Fuatbey 2000 durum wheat variety, also Amanos 97 was bred by Çukurova Agricultural Research Institute and it is its good resistance to stripe rust and seproria and medium resistance to leaf rust. Its resistances to cold and drought are good and medium, respectively.

According to the color ranking of spaghetti products, the sample produced Amanos 97 durum wheat variety gets 4th rank with its color index which is 42.90. About its cooking quality scores; its firmness was evaluated as 65 while its bulkiness and stickiness were 60 and 55, respectively.

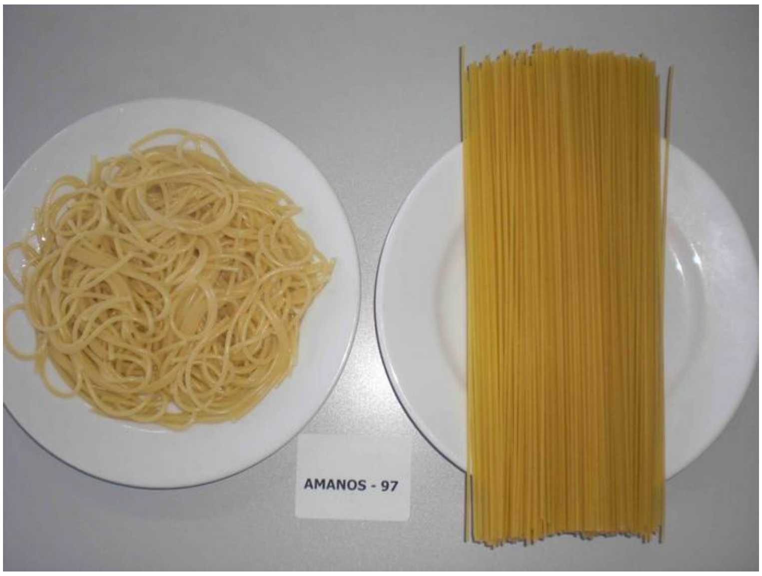

Figure 28 Cooked and uncooked spaghetti produced from Amanos 97 variety

3.7.9. Sarıçanak 98

Sarıçanak genotype was bred by Southeast Agricultural Research Institute. It is known with its strong resistance against wheat bunt and wheat smut.

Considering to test results for the cooking quality parameters, the spaghetti sample produced from Sarıçanak 98 variety can be ranked at the last place with the sample produced from Ç-1252 variety (bulkiness = 60, stickiness = 55, firmness= 60).

By its yellowness index, 42.24, it gets 5th rank for color ranking in all samples.

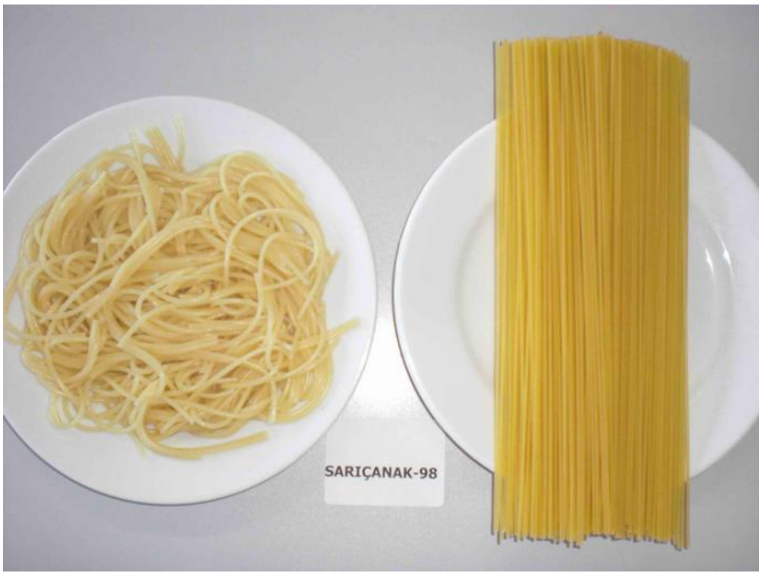

Figure 29 Cooked and uncooked spaghetti produced from Sarıçanak 98 variety

3.7.10. Çeşit 1252 (Ç-1252)

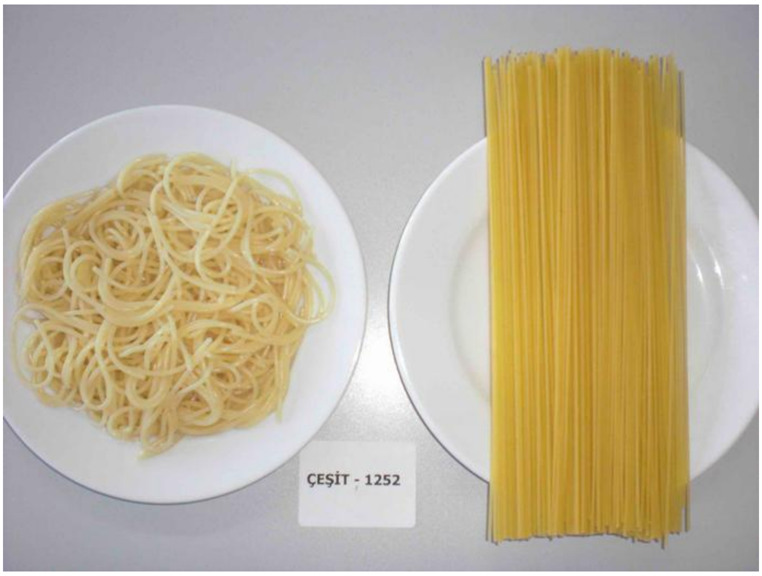

Figure 30 Cooked and uncooked spaghetti produced from Çeşit 1252 variety

The spaghetti sample produced from this variety ranks the last place for cooking evaluation, and 9th place for color evaluation (bulkiness = 60, stickiness = 55, firmness= 60 and indices b = 41.62).

CHAPTER 4

CONCLUSION

In Turkey, more than 40 Durum wheat varieties have been cultivated. Especially in the recent years, 10 of the durum varieties representing 80% of total durum wheat production used by pasta manufacturers, which are Amanos 97, Çeşit 1252, Ege 88, Fırat 93, Fuatbey 2000, Burgos, Kızıltan 91, Sarıçanak 98, Svevo and Zenith. In this study, these varieties and the spaghetti products produced from these varieties were analyzed.

The cooking quality parameters (bulkiness, stickiness, firmness) and cooking loss of spaghetti samples produced from Svevo, Zenith and Fırat 93 varieties get the higher scores than others. These varieties have higher protein and gluten quantity and quality so higher scores about cooking quality parameters come from these conditions. These scores are in agreement with a lot scientific researches those stated the relations between cooking quality and protein fractions. The spaghetti samples produced from Sarıçanak 98, Amanos 97, and Çeşit 1252 were evaluated low in stickiness score (more stick and starch release) and those produced from Sarıçanak 98, Çeşit 1252, Kızıltan 91, and Fuatbey 2000 were evaluated low for firmness.

About the cooking loss, the spaghetti sample produced from Svevo, Zenith and Fırat 93 get the highest scores with low cooking loss. The samples produced from Çeşit 1252, Sarıçanak 98 and Amanos 97 gave more solids to cooking water.

In this study, we considered only the quantity and quality of protein and gluten. So in this study it is impossible to show which protein's fractions (glutenin/gliadin ratio, amount of HMW-GS (high molecular weight glutenin subunits) or LMW GS (low molecular weight glutenin subunits), γ-Gliadin types (γ -42 or γ -12) of these varieties are the main responsible for having high or low cooking quality scores. Further researches can be done to define these fractions for each variety and their effects on cooking quality.
Some scientific researches state that the good cooking quality of pasta has also been related to starch gelatinization properties (Resmini and Pagani, 1983; Delcour et al., 2000a, b). So, evaluating starch properties and their effect on cooking quality parameters can be another study for these durum wheat varieties.

The highest yellow indices (b indices) belong to spaghetti samples which are produced from Svevo, Burgos and Zenith varieties. The b indices of other samples ranked in between 40.71 and 42.90 which are acceptable values for pasta manufacturers.

In general, spaghetti samples produced from Svevo and Zenith varieties have the best scores in all quality parameters. Unfortunately, these 2 varieties have been bred by an Italian Company and Svevo is still an exclusive variety and released 5 years ago. Other varieties which were bred locally can be rated as medium quality but poor in terms of color and gluten quality compared to Svevo and Zenith.

Recommendation is that, when breeding new varieties, scientists and breeders, should focus on these two criteria to improve the quality of pasta produced in Turkey.

Another important point is that, physical purity vitreousness (more than 90%), and absence of soft wheat in the blend of the wheat used is an important factor on quality.

According to the experiences of Turkish pasta producers which were declared by TMSD (Association of Turkish Pasta Manufacturers), variety Çeşit-1252 is the worst variety of Durum wheat in Turkey.

But results showed that, when this variety milled alone in a pure form, result is not as TMSD officials declared and almost has the same quality characteristics as other local varieties.

Protein content, gluten quality, and color are the main requirements of raw materials in order to obtain pasta of very acceptable quality. Therefore the characteristics of final product are linked in turn the influence of genotype and cultivation environment. (Mariani et al, 1995); in fact the protein content is highly dependent on the environment (locality, year, etc.); while the gluten quality and color are mainly affected by genotype (D’Eglio and Pagani, 2010). So, the quality parameters of durum wheat depend on both genotype~~s~~ and environmental conditions (location, growing condition, year, etc.). Further studies depending on not only genotype but also genotype and environmental conditions can be performed and the results of these studies will give appreciated supports and approaches to both durum wheat producers and pasta manufacturers.

As conclusion,

Zenith and Svevo varieties are the ones which fits the end user needs. Whereas, Ç-1252 is the worst variety and it should be deleted from the certified seeds list.

Another important result to be pointed out is that almost all of the local varieties have similar characteristics. AS per the results of study, what we can recommend for the future is that, instead of breeding new varieties which needs long times (12-15 years), researchers should focus on the present varieties and develop their “weak” characteristics from the end user point of view.

A good example for this is the Canada. Being the biggest exporter of Durum wheat (Source: IGC monthly and annual reports), Canada has only 14 Durum wheat varieties but they are “re-developed” several times as per the needs of the pasta industry.

Importance and particularity of this thesis is that it has been carried out in an industrial scale plant instead of laboratory scale. This is important to have a result which can be used directly by the industry and by other parties working on similar subjects.

This is also important for giving quick decisions for the future instead of waiting for the industrial results of laboratory scale studies.

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APPENDIX 1

Technological Standard Sheet

"Ürün Reçetesi/ *Technological Standard Sheet* "		Tarih/ *Date:*	Kontrol Tarihi: *Date Check:*	Onay Tarihi: *Date Approved:*
Bolu Fabrika/ *Plant* **SPAGHETTI**		01.04.2009 Sorumlu/ *By* Okkaoglu I.	01.04.2009 Sorumlu/ *By* Nespoli A.	01.04.2009 Sorumlu/ *By* Dameno F. Çetiner M.
Hat/ *Line:* 107				
		Revizyon numarası/ *Revision Number* N° 003		
		Şekil/ *Shape #*	5	Spaghetti
	Şekil İsmi/ *Shape name*	**Spaghetti**		
		Proses Değerleri/ *Variables Values*		
		Birim *Units*	**Değer *Value***	**Tolerans *Tolerance***
İrmik Besleme *Semolina feeding*	İrmik Miktarı / *Semolina mass flow*	Kg/saat *Kg/h*	**2100**	**± 100**
Su Besleme/ *Water feeding*	Su Oranı / *Water percent*	%	**28,0**	**± 3**
	Hamur Suyu Sıcaklığı/ *Water feeding temperature*	°C	**50**	**± 10**
Vakum/ *Vacuum*	Vakum seviyesi/ *Vacuum level*	mm - Hg	**600,0**	**± 50**
Pres/ *Press*	Vida Sıcaklıkları/ *Cylinder temperatures*	°C	**35,0**	**± 5**
------------------------	Kafa Sıcaklıkları/ *Head temperatures*	°C	**40,0**	**± 5**
------------------------	1.Vida Hızı/ *Screw Speed 1*	rpm	**23,5**	**± 1**
------------------------	2.Vida Hızı/ *Screw Speed 2*	rpm	**23,5**	**± 1**
------------------------	Vida Basıncı/ *Screw Pressure*	Bar	**100**	**± 10**
Filtre sayısı/ *Die screen no.*			**2**	
Dağıtıcı / *Spreader*	Üç Lata Zamanı / *Loading cycle*	Saniye / *sec*	**35,5**	
Kafa Üfleme Sıcaklığı/ *Temperature Fans*		°C	**70**	**± 10**
Ön Ön-Kurutma 1.Bölge *Pre Predryer Z1*	Sıcaklık/ *Temperature*	°C	**49,0**	**± 1**
------------------------	Delta	°C	**10,0**	**± 1**
------------------------	Bağıl Nem/ *Humidity*	%	**52,0**	**± 2**
------------------------	Eksoz Valfi Açıklığı/ *Humidity valve out*	Psi	**11,0**	**± 1**
------------------------	Sıcaklık valfi açıklığı/ *Temperature valve out*	Psi	**5,0**	**± 1**
Ön Ön-Kurutma 2.Bölge *Pre Predryer Z2*	Sıcaklık/ *Temperature*	°C	**53,5**	**± 1**
------------------------	Delta	°C	**8,0**	**± 1**
------------------------	Bağıl Nem/ *Humidity*	%	**62,0**	**± 2**
------------------------	Eksoz Valfi Açıklığı/ *Humidity valve out*	Psi	**11,5**	**± 1**
------------------------	Sıcaklık valfi açıklığı/ *Temperature valve out*	Psi	**6,0**	**± 1**
Ön-Kurutma 1.Bölge *Predryer Z1*	Sıcaklık/ *Temperature*	°C	**58,0**	**± 1**
------------------------	Delta	°C	**5,8**	**± 1**
------------------------	Bağıl Nem/ *Humidity*	%	**72,0**	**± 2**
------------------------	Eksoz Valfi Açıklığı/ *Humidity valve out*	Psi	**11,0**	**± 1**
------------------------	Sıcaklık valfi açıklığı/ *Temperature valve out*	Psi	**7,0**	**± 1**
Ön-Kurutma 2.Bölge *Predryer Z2*	Sıcaklık/ *Temperature*	°C	**68,5**	**± 1**
------------------------	Delta	°C	**6,8**	**± 1**
------------------------	Bağıl Nem/ *Humidity*	%	**72,0**	**± 2**
------------------------	Eksoz Valfi Açıklığı/ *Humidity valve out*	Psi	**9,0**	**± 1**
------------------------	Sıcaklık valfi açıklığı/ *Temperature valve out*	Psi	**5,0**	**± 1**
------------------------	Ön Kurutma Çıkış Nemi/ *Moistness of product*	%	**18,0**	**± 1**
------------------------	Ön Kurutma Süresi / *Pre-Dryer Residence time*	saat:dak/ *hours:min*	**0:45:00**	
GPL 1	Sıcaklık/ *Temperature*	°C	**78,0**	**± 1**
------------------------	Delta	°C	**6,8**	**± 1**
------------------------	Bağıl Nem/ *Humidity*	%	**74,0**	**± 2**
------------------------	Eksoz Valfi Açıklığı/ *Humidity valve out*	Psi	**9,0**	**± 1**
------------------------	Sıcaklık valfi açıklığı/ *Temperature valve out*	Psi	**3,5**	**± 1**
GPL 2	Sıcaklık/ *Temperature*	°C	**79,0**	**± 1**
------------------------	Delta	°C	**6,6**	**± 1**
------------------------	Bağıl Nem/ *Humidity*	%	**75,0**	**± 2**
------------------------	Eksoz Valfi Açıklığı/ *Humidity valve out*	Psi	**10,0**	**± 1**
GPL 3	Sıcaklık/ *Temperature*	°C	**86,0**	**± 1**
------------------------	Delta	°C	**10,6**	**± 1**
------------------------	Bağıl Nem/ *Humidity*	%	**64,0**	**± 2**
------------------------	Eksoz Valfi Açıklığı/ *Humidity valve out*	Psi	**9,0**	**± 1**
------------------------	Sıcaklık valfi açıklığı/ *Temperature valve out*	Psi	**6,0**	**± 1**
------------------------	M-1 Çıkış Nemi/ *Moistness of product*	%	**13,0**	**± 1**
------------------------	İkinci Kurutma Süresi / *GPL Residence time*	saat:dak/ *hours:min*	**5:00:00**	
Sıcak Şoklama/ *Gradual Cooler*	Sıcaklık/ *Temperature*	°C	**72,0**	**± 3**
------------------------	Delta	°C	**3,0**	**± 2**
------------------------	Bağıl Nem/ *Humidity*	%	**88,0**	**± 2**
	Süre / *Residence time*	saat:dak/ *hours:min*	**0:25:00**	
Soğutma / *Cooler*	Sıcaklık/ *Temperature*	°C	**36,0**	**± 3**
------------------------	Delta	°C	**5,0**	**± 2**
------------------------	Bağıl Nem/ *Humidity*	%	**60,0**	**± 2**
	Süre / *Residence time*	saat:dak/ *hours:min*	**0:25:00**	
Hat Çıkış Nemi / *Moistness After Cooler*		%	**11,5**	**± 1**
Toplam Kurutma Süresi / *Total residence time*		saat:dak/ *hours:min*	**6:35:00**	
Toplam Hat/ *Total Line*	Randıman/ *Productivity*	Kg/saat *Kg/h*	**1950**	**± 50**

APPENDIX 2

1. Gluten Quantity and Gluten Quality Analysis

The gluten quantity and quality of all samples were measured by the following method:

1.1. Scope:

To measure and describe the method for the determination of the quality evaluation of gluten of wheat and semolina using Glutograph and quantitative analysis

1.2. Principle:

Dough is prepared by mixing the milled durum wheat or semolina with a buffered solution of sodium chloride; the wet gluten is isolated by leaching and washing the dough with Glutomatic using the same solution. The Glutograph is used for the qualitative analysis. For the quantitative analysis, the gluten is dried and weighed.

1.3. Reagents:

- Distilled water.
- Sodium chloride.
- Sodium chloride, washing solution 2% p/v
    - Weigh (7.1) 20 g of sodium chloride (6.2).
    - Dissolve (7.9) in 1 litre of distilled water (6.1).
    - Mix well.

1.4. Apparatus:

- Balance, precision 0.01 g.

- Perten Glutomatic 2200 – Gluten washer.
- Brabender Glutograph.
- Automatic doser supplied with the gluten washer.
- Chronometer.
- Mercury thermometer or digital thermometer with Pt100 probe.
- Laboratory mill Cyclotec Mod.1093 with grid of 0.5 mm diameter.
- Metallic sieve with a nominal mesh opening of 20 x 1.9 mm.
- Glass calibrated flask, 1000 ml capacity.

1.5. Procedure:

1.5.1. Sample preparations:

Durum wheat

- Weight 70 g of durum wheat.
- Pour the weighted sample on the metallic sieve.
- Sieve manually.
- Eliminate all impurities and extraneous material.
- Collect the sample held in the metallic sieve and mill.
- Slowly feed the mill avoiding grid obstruction.
- Accurately mix the milled sample.
- Let cool the milled sample until room temperature is attained.

Semolina

Analyze as it is.

1.5.2. Dough preparation and washing

- Always prepare 2 dough samples for every sample

- Weigh 10 g of milled durum wheat or semolina.

- Distribute the milled durum wheat or semolina evenly in the baskets, smoothing off using your hands.

- Add 5 ml of sodium chloride, solution 2 % using the dosing equipment supplied.

- Make sure that the solution does not leak from the bottom of the basket but is completely absorbed by the sample.

- Position the baskets in the instrument locations.

- Make sure that the “Wash meal” button has been pressed and that the corresponding yellow light is ON.

- Press the following buttons in this order:

“Wash meal”

“Reset”

“Start”: this starts the mixing stage (20 s) which is followed by the first washing stage (2 minutes).

- At the end of the first washing stage (a buzzer sounds), Glutomatic stops automatically. - Dismantle the baskets.

- Using the plastic collar, pour the gluten into the second basket (which has a lined outer edge) to which the 840 μ mesh grid has been fitted in advance.

- Do this under a flow of water (normal) which helps you to transfer all the material remaining at the bottom of the first basket (with 88 μ filter) when it is removed from Glutomatic.

- After transferring the material, position the second set of baskets on Glutomatic.

- Press “Start”: this starts the second washing stage (3 minutes).

- At the end of the second washing stage (a buzzer sounds), Glutomatic stops automatically.

- Remove the baskets.

- Collect the gluten from the bottom of the basket or from the rotary hook.

- Avoid over-stretching the gluten.

- The gluten must now be set to rest in the open air and must not be manipulated in any way.

1.5.3. Gluten rest:

Leave the gluten for 5 minutes in the open air.

1.5.4. Gluten quality evaluation – Glutograph:

- Transfer the sample obtained from the first washing cycle of Glutomatic in the central part of the lower toothed disk on the Glutograph.
- Position it so that it maintains the same position as during the rest stage (the lower part in contact with the table during the rest stage must now be fully in contact with the lower toothed disk).
- Lower the upper toothed disk.
- Tighten the closing mechanism.
- Cut the surplus edge of gluten with a rapid downwards movement, rotating it in an anti-clockwise direction at the same time to assist the work of the knife.
- Move the knife back to its original position
- Remove any bits of gluten stuck to the lower cylinder.
- Turn ON the instrument by pressing “Start”.
- The instrument stops automatically when the pen reaches the 800 B.U. line or when 126 seconds have elapsed, regardless of the position of the pen.

Repeat these operations for the gluten obtained from the second washing cycle of Glutomatic.

1.5.5. Gluten quantity

- Mix the two gluten samples from the Glutograph test with the surplus gluten cut from the samples previously.
- Dry gluten by pressing it between the palms of your hands.

- Continue this operation until the weight stops decreasing.
- Weigh gluten: P

1.6. Expression of Results:

Gluten quality is expressed with one decimal place. Gluten weight is expressed with one decimal place

1.7. Method of calculation and formulas:

1.7.1. Qualitative analysis:

Depending on the quality of the gluten, we can have two reading conditions:

i) Time in seconds (to be read on the display, considering that the third digit represents tenths of a second) if the pen had reached the 800 B.U. line within 126 seconds.

ii) B.U. value (read the B.U. value corresponding to the point reached by the pen), if the pen had not reached the 800 B.U. line within 126 seconds.

To obtain an evaluation on a decimal scale, use the following equations:

$$\text{Evaluation} = 2.66 + 0.96 \times \text{Ln sec.}$$

$$\text{Evaluation} = 9.92 - 3.35 \times (\text{B.U.}/ 1000)$$

Where:

Ln sec = natural time logarithm (expressed in seconds).

B.U. = Brabender Units

1.7.2. Quantitative analysis:

The gluten content, expressed as %, is:

$$\% \text{ gluten} = \frac{P \times 5}{3}$$

$$\% \text{ gluten (dried matter)} = \frac{P \times 5}{3} \times \frac{100}{100 - U}$$

Where;

P = Dried gluten weight, in grams

U = % Sample moisture

1.7.3. Repeatability:

The difference between the results of two single determinations carried out simultaneously or in rapid succession by the same analyst shall not exceed the following value:

Evaluation: ± 0.15

If the differences are greater, the analysis must be repeated.

APPENDIX 3

1. Cooking Quality Analysis

The cooking quality parameters of all samples were measured by the following method:

1.1. Scope:

To describe the method for cooking pasta and for manual analysis of characteristics of the cooked pasta to check that it meets the product standards for the particular reference pasta cuts.

1.2. Terms and Definition:

Bulkiness: the ability of one piece of pasta to slide smoothly against another.

Stickiness: State of surface breakage of the cooked pasta, with release of finger.

Firmness: Resistance of the cooked pasta to squashing between the fingers.

1.3. Apparatus:

- Balance, precision 0.001 g.
- Steel pots with lids, 2 liter capacity.
- A colander for pasta, plates and a fork.
- Hot plates.
- Chronometer.
- Graduated cylinder, 1 liter capacity.

- Glass beaker, 250 ml capacity.
- Reference pasta samples of which cooking characteristics (bulkiness, stickiness, firmness) have been predefined.

1.4. Procedure:

- Weigh 80 g of pasta.
- Only for long cuts break the pasta in two parts and eliminate any small bits before weighing.
- Turn on the hot plate, always positioning the plate knob in the same way to ensure that the cooking speed conditions are always the same.
- Place the 2-liter steel pot containing 1300 ml of tap water measured using a graduated cylinder on the hot plate.
- Boil the water.
- Keep the water close to boiling point so that it can be brought back to boiling point as soon as the pasta is added.
- Add the pasta sample in the pot and start the chronometer at the same time
- Cook the pasta for the time indicated by product standards.
- For the first minute, leave the pot fully closed. For the remaining time, the lid must be moved slightly to the side.
- While the pasta is cooking, mix it with a fork 3 times for 10 seconds. Do this at 1.4, 1.2 and 3.4 of the cooking time.
- When the pasta is cooked (8 minutes for spaghetti which are subject for this project), cool the water by adding 200 ml of cold tap water into the pot using a beaker.
- Drain the pasta immediately, hitting the colander 3 times (7.3).
- Pour the pasta onto the plate.
- Leave the cooked pasta to the plate for 5 minutes.
-Test the pasta using the hands.

1.5. Test methods:

1.5.1. Bulkiness:

- Wet your hands and shake off the excess water.
- Pick up handful of pasta and drop it onto the plate.
- Repeat the operation three times.

Using the reference samples for comparison, test the way in which the pieces of pasta separate from each other and the way they drop onto the plate.

1.5.2. Stickiness:

- Wet your hands and shake off the excess water.
- Put your on the pasta and rub it with the palm of your hands and your fingers.
- Repeat the operation three times.

Using the reference sample for comparison, evaluate the amount of starch on your hands and fingers.

1.5.3. Firmness:

-Wet your hands and shake off the excess water.
- Place two pieces of pasta in the front end of index finger and press it with your thumb until both pieces break.
- Repeat the operation approximately 10 times.

Using the reference samples for comparison, evaluate the effort required to break the pasta pieces.

1.6. Expression of Results:

The results are expressed by an integer number in relation to a defined scale for the three parameters tested.

Score the sample tested, referring to the evaluation scale stipulated for the three parameters: Bulkiness, stickiness and firmness

Table 1 Evaluation scale for cooking quality

Bulkiness	**Stickiness**	**Firmness**
90	90	90
80	80	80
70	70	70
60	60	60
50	50	50

APPENDIX 4

1. Color Analysis (Wheat)

Colors of all samples were measured by the following method:

1.1. Scope:

To describe the method for the determination of color or “b” index of durum wheat kernels

1.2. Method:

Kernels are taken the barks off to remove bran part, which would cover yellow component and later grinder.
Intrinsic color is identified using only one definite band of flour particle size to limit the variability due to grinding and by evaluating the color using the Minolta colorimeter.

1.3. Apparatus and Reagents:

- MT-0020 –Minolta CR300 colorimeter.
- Satake debranner TM 50.
- Buhler grinder MLI 205.
- Technical balance, precision 0.01 g.
- Minolta CR 300 colorimeter.
- CR A-50 accessory for powder.
- White reference plate.
- Buhler MLI 300 type sieve unit with eccentric movement.

- Series of sieves for Buhler sieve unit with diameter of 200 mm and three 42 cm chains secured to the inside at 120° with nytal filter with mesh 200 μ
- Series of sieves for Buhler sieve unit with diameter of 200 mm and three 42 cm chains secured to the inside at 120° with nytal filter with mesh 160 μ
- Collection plate.
- Plastic bowl.
- Small rubber hammer.
- Soft bristle brush.

1.4. Procedure:

1.4.1. Instrument preparation:

Calibrate the instrument by carefully positioning the measurement head of the optic lens of the CR A-50 accessory on the white reference plate supplied and select the color space Y x y (with D65 light) in the CieLab system.

At the end of calibration, return to color space "**L" "a" "b"** and press 8 [PAGE] and 16 [ENTER] to set up the color meter for reading the samples

1.4.2. Sample preparation:

- Pick up a wheat sample of about 250 grams.
- Clean wheat accurately using metallic sieve.
- Divide sample into two portions of about 100 grams each.
- Pass two samples separately from Satake debranner for 4 minutes.
- Assemble two barked portions and grind.
- Do grinding a first time with grinder regulation on nr.9 (gross grinding).
- Then repeat grinding on position nr. 4.

- The particle size of flour product must be so that waste on film 160 μ is contained between 10 and 12 g.

-Mix sample accurately.

- Mount the sieves fitted with the Nytal filters with 200 and 160 μ mesh size with 200 above and 160 below.

- Place the collection plate underneath the sieves.

- Place this set on the sieve unit.

- Weigh 100 g of semolina.

- Pour the semolina onto the 200 μ sieve.

- Secure the cover carefully.

- Sieve for 5 minutes.

- At the end of the sieving, carefully eliminate the bits still under the 160 μ filter by hitting the sieve gently with a small rubber hammer.

- Collect the remains from the 160 μ filter in a plastic bowl.

- Homogenize.

- The colorimeter analysis is carried out on the material which remains in the 160 μ filter sieve.

1.4.3. Colorimeter reading:

- Take one part of the sample and carry out the colorimeter reading using the CR A-50 cell

- Place this sample part back in the container (7.9) and mix again.

- Repeat the reading for 3 different parts of the sample.

1.5. Expression of Results:

The color result is expressed by the “b” index or yellow level with one decimal place.

1.5.1. Calculation method:

Using the colorimeter software, automatically calculate the mean and the standard deviation for the readings made for every sample part.
The test result is the mean of the 3 results for the three sample part readings.

1.5.2. Repeatability:

The standard deviation between the values obtained from 3 simultaneous readings or readings in rapid succession was less than 0.20 for the “b” index for all samples.

2. Color Analysis (Semolina)

2.1. Scope:

To describe the method for the determination of color or “b” index of durum wheat semolina

2.2. Method:

Intrinsic color is identified using a defined granulation range for the milled product to limit the variability caused by the re-composition of industrial fractions of semolina and by evaluating the color using the Minolta colorimeter.

2.3. Apparatus:

- Minolta CR 300 colorimeter
- CR A-50 accessory for powder
- White reference plate
- Technical balance, precision 0.01 g
- Buhler MLI 300 type sieve unit with eccentric movement
- Series of sieves for Buhler sieve unit with diameter of 200 mm and three 42 cm chains secured to the inside at 120° with nytal filter with mesh 200 μ
- Series of sieves for Buhler sieve unit with diameter of 200 mm and three 42 cm chains secured to the inside at 120° with nytal filter with mesh 160 μ
- Collection plate
- Retsch type sieve unit, mod. AS 200 Control "G"
- Series of metal sieves for Retsch sieve unit, as per DIN-ISO3310/1 standard with mesh of 200 μ
- Series of metal sieves for Retsch sieve unit, as per DIN-ISO3310/1 standard with mesh of 160 μ
- Collection plate
- Glass balls, diameter 0.5 mm, n.°80
- Plastic bowl
- Small rubber hammer
- Soft bristle brush

2.4. Procedure:

2.4.1. Instrument preparation:

Calibrate the instrument by carefully positioning the measurement head of the optic lens of the CR A-50 accessory on the white reference plate supplied and select the color space Y x y (with D65 light) in the CieLab system.

At the end of calibration, return to color space "**L" "a" "b"** and press 8 [PAGE] and 16 [ENTER] to set up the color meter for reading the samples

2.4.2. Sample preparation:

- Mount the sieves fitted with the Nytal filters with 200 and 160 µ mesh size with 200 above and 160 below.
- Place the collection plate underneath the sieves.
- Place this set on the sieve unit.
- Weigh 100 g of semolina.
- Pour the semolina onto the 200 µ sieve.
- Secure the cover carefully.
- Sieve for 5 minutes.
- After sieving, carefully eliminate the bits still under the 160 µ filter by hitting the sieve gently with a small rubber hammer or using a soft bristle brush.
- Pass the remains from the 160 µ filter through a broad mesh sieve to recover the glass balls.
- Collect the remains from the 160 µ filter passed through the broad mesh sieve in a plastic bowl and homogenize.
- The colorimeter analysis is carried out on the material which remains in the 160 µ filter sieve.

2.4.3. Colorimeter reading:

- Take one part of the sample and carry out the colorimeter reading using the CR A-50 cell.
- Place this sample part back in the container and mix again.

- Repeat the reading for 3 different parts of the sample.

2.5. Expression of Results:

The color result is expressed by the "b" index or yellow level with one decimal place.

2.5.1. Calculation method:

Using the colorimeter software, automatically calculate the mean and the standard deviation for the readings made for every sample part.
The test result is the mean of the 3 results for the three sample part readings.

2.5.2. Repeatability:

The standard deviation between the values obtained from 3 simultaneous readings or readings in rapid succession were less than 0.20 for the "b" index for all samples.

3. Color Analysis (Pasta-Spaghetti)

3.1. Scope:

To describe the method for the determination of color of spaghetti

3.2. Principle:

The apparent color of all pasta cuts is determined directly using a Minolta CR410 colorimeter with a very large reading spot.

3.3. Apparatus:

- Minolta CR410 colorimeter.
- Minolta accessory: special extension tube for CR 410 without reflection-proof glass.
- PTFE collar dimensions: outer diameter 70 mm, inner diameter 56 mm and height 45 mm. This is inserted on the extension tube to facilitate reading head positioning on the containers used for the pasta samples.
- Rectangular Plexiglas container with dimensions of 275 x 94 and height of 65 mm, including a cover with three 55 mm diameter holes.

3.4. Procedure:

3.4.1. Instrument preparation:

Calibrate the instrument by carefully positioning the measurement head with the extension tube fitted with the white collar on the white reference plate and select the color space Y x y (with D65 light) in the CieLab system.

At the end, return to color space "**L" "a" "b"** and press 8 [PAGE] and 16 [ENTER] to set up the color meter for reading the samples

3.4.2. Sample preparation:

- Use approximately 500 g of spaghetti pasta.
- Position the pasta sample inside the rectangular container and remove all pieces of crooked pasta.
- Compress the sample inside the container using the special cover with 3 holes.

3.4.3. Colorimeter reading:

- Take 3 color meter readings, one from each of the 3 holes on the container cover.
- Rotate the pasta sample inside the container through 180°.
- Take another 3 color meter readings, one from each of the 3 holes on the container cover.
- The final result is the mean of the 6 color meter readings.

3.5. Expression of Results:

The pasta color result is expressed using the “a” index (red-brown) and the “b” index (yellow).

3.5.1. Method of calculation:

Calculate automatically for each index, using the color meter software, the mean and the standard deviation for the different readings made for every sample part.
The result is the mean of the color meter reading results taken for long pasta and short pasta.

3.5.2. Repeatability:

The standard deviation obtained from the calculation of the mean values for the indices were less than 0.15 for all samples.