Desert Durum Wheat Provides High-Quality Extraction and Pasta Products

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Desert Durum is a registered brand name for durum wheat grown in the southwestern United States. Approximately 700,000 t of the durum is grown in California and Arizona each year. The leading varieties are Alamo, Crown, DuraKing, Kofa, and Kronos. Desert Durum is used primarily by millers and pasta producers outside the United States who are aware of its advantages and are processing it with very good results.

With relatively few changes in a durum mill, the mill operator can adjust the milling process for Desert Durum to produce high semolina extraction, high quality, and high potential economic value. Wheat cleaning, tempering time, and roll corrugation are the main parameters that need to be evaluated and adjusted to meet the specific requirements for semolina and other product applications. Changes should be made based on detailed mill analysis that includes construction of a distribution table and granulation curves for the leading stages in the mill.

Desert Durum wheat is planted during December and February and harvested during May and June, when temperatures in the southwestern United States can reach 42°C and 10% RH. Average moisture content during harvest is between 6 and 7%. Desert Durum yield is approximately 2,722–4,082 kg/acre (100–150 bu/acre) compared with approximately 1,090–1,333 kg/acre (40–50 bu/acre) for conventional durum grown in the northern United States. The higher yield per acre is a result of precise irrigation and the ability to incorporate fertilizers at specified levels timed with irrigation water. Desert Durum wheat enters the market up to 3 months ahead of conventional durum harvested in northern North America. On average, two-thirds of the Desert Durum crop is sold in advance, and at times premiums as high as \$15–20/t can be obtained.

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Desert Durum varieties have been specifically adapted to be grown using irrigation under desert conditions. The result is large, uniformly sized kernels with high specific weight (>81 kg/hL) that have the potential to produce very high levels of extracted clean endosperm product in the mill. Grown under dry climate conditions, these wheat varieties usually have a very high falling number (FN) that indicates no sprouting before harvest, spotted or dark kernels, or ergot (*Claviceps purpurea*) and a minimum of broken kernels.

Durum wheat affected by sprout damage results in the breakdown of starch by α- and β-amylases. If the FN is <150 sec, long goods will stretch during drying and may break. Matsuo and coworkers (10) found that the FN test is highly correlated with durum wheat α-amylase activity and is a good indicator of sprout damage. The critical factor affecting end-use quality is the level of α-amylase in the processed product. High amylolytic activity in spaghetti increases the amount of residue in the cooking water and the level of reducing sugars in both semolina and spaghetti and tends to produce slightly softer cooked spaghetti. Conflicting statements have been made regarding the effect of sprout damage on milling and spaghetti color. Matsuo and coworkers (10), Dick and coworkers (5), and Dexter and coworkers (4) stated that semolina yield and spaghetti color did not appear to be significantly affected by sprout damage, whereas Donnelly (6) and D'Egidio (3) stated that semolina from sprouted wheat might be higher in speck count or susceptible to Maillard reaction during pasta processing.

The enzymatic activity of the amylases depends on genotype and environment. One explanation for the conflicting statements on the effect of α-amylase on semolina extraction is the inability to measure its progression from the scutellum and aleurone into the endosperm during germination. The technology used in milling to produce semolina also affects the contamination of mill streams with α-amylase that might exist only in the outer layer of the kernel. However, α-amylase is active only on damaged starch granules, and the level of starch damage can be controlled in the semolina by the miller using an appropriate flow sheet and durum mill adjustment.

Mill operators are constantly looking for new opportunities and technologies for processing wheat. Millers who process a commodity and deliver a raw material need to use every opportunity to generate a profitable margin from the operation, and Desert Durum provides a promising opportunity. In plants where the mill and pasta manufacturing lines are integrated, there is the potential for a large profit. This is due to the moisture difference between the purchased wheat (6-7%) and prepared pasta (≈12%). This advantage is especially evident when exporting very dry wheat by ship to durum mills around the world. Experience has shown that after being loaded on a ship moisture is absorbed by the wheat during transport, pneumatic handling, and initial cleaning at the destination elevator. From ship loading through the handling stages, the moisture of a Desert Durum variety can reach ≈8–9%.

A good tool for evaluating the milling characteristics of incoming wheat is the batch-type experimental mill. Li and Posner (9) have described a method for analyzing hard wheat that could also be used for durum wheat. However, if enough wheat is on hand, the best assessment of wheat quality can be achieved when the wheat is milled on a commercial mill that is finely adjusted to the physical characteristics of the kernels.

This article includes information from two separate runs of Desert Durum on two different commercial milling units. Both mills were part of integrated milling and pasta line plants located in Central and South America. The Desert Durum wheat loads were ≈100 t each and were supplied by U.S. Wheat Associates, Inc. under the Sample Quality Program. The diversity of equipment, flow sheets, and methods used in the mills and the different semolina specifications for the pasta lines did not allow direct comparison of performance between the mills. Therefore, results achieved with the Desert Durum wheat are compared with results achieved with other commercial durum processed on the same milling units. The commercial durum used was a Canadian Western Amber Durum (CWAD), 'Navigator'. Navigator was graded CWAD

No. 2 because the percentage of hard vitreous amber color (HAVC) kernels was 76.3%. To be designated as a No. 1 grade, a minimum of 80% HAVC is necessary.

Specific Technical Requirements in the Durum Mill

When durum wheat arrives at the mill, proximate analysis and physical characteristics should be determined in the laboratory to supply the mill operator with the information needed for efficient processing. Laboratory analysis should determine characteristics such as kernel size distribution, hardness, thousand-kernel weight, shape, and density. Such data provide the miller with measures for fine adjustment of the precleaning, final cleaning, and milling processes.

Durum Wheat Cleaning. Durum wheat cleaning must be very efficient because if impurities remain in the wheat they are reduced during the milling process and are noticeably in the final semolina, which is a granular material. For example, ground stone particles that end up in semolina reduce pasta quality and can damage the pasta extruder die. Accordingly, a durum wheat cleaning system must include high-quality equipment with more flexibility and fine adjustment capabilities. Abecassis (2) found that in general the investment made in durum cleaning systems is one-third of the total, whereas in flour milling plants it is about one-fourth of the total.

Some milling operations are multiple-purpose mills that are intended to grind hard and durum wheats (swing mills). Significantly more cleaning equipment and flexibility is required in mills where durum and hard wheats are alternately processed. Some cleaning systems use machinery in which more than one principle for separating unmillable materials based on kernel size, shape, and specific gravity are used. Particularly in swing mills, such combinations, which are aimed at reducing the number of machines in the cleaning section, should be avoided. Ample air and sieve areas should be available in durum and swing mill cleaning systems.

There are significant differences in the physical characteristics of the wheat that should be considered when switching from hard to durum wheat and even between loads of each kind of wheat. In addition to machine adjustments for efficient separation of unmillable materials, wheat load to the machines may vary based on the specific physical characteristics of the wheat. For example, Desert Durum wheat kernels are larger and more uniform than conventional durum. Accordingly, screens in separators should be changed to allow all whole large kernels to pass through the upper sieve and broken kernels to pass through the lower sieve. Indent and disk separators should be inspected to allow accurate separation of any foreign material larger or smaller than the wheat based on shape. The larger Desert Durum kernels require larger pockets in disk and indent separators. Accordingly, in the durum cleaning system it is an advantage to use disk separators with split disks that can be changed easily if necessary. This is especially important in the long kernel sections, where larger kernels may tail over into screenings if larger disk pockets are not included in the machine arrangement. Spiral separators for separation of broken kernels from wild and other grain seeds is recommended as part of the durum cleaning system. Clean, broken durum kernels, especially if found in Desert Durum, can still be directed to tail-end breaks to gain additional endosperm extraction. Extra efforts should be taken with the air adjustment of gravity tables and destoners to separate any stones that may be found in durum wheat characterized by high density.

Conditioning. One of the main challenges in milling Desert Durum is the wheat conditioning that occurs prior to milling. Arrangements should be made in the mill to accommodate the need for adequate water penetration by providing sufficient tempering bin capacity or through other means. In general two conditioning stages can be used for Desert Durum. In the first stage, water added to the wheat followed by a tempering period results in the creation of internal fissures in the kernel. In the second stage, more water is added, and the capillary spaces in the fissured endosperm allow faster water absorption. Accordingly, adjustments should be made in the mill to add ≈40% of the needed milling moisture during the first conditioning stage and 60% during the second stage.

The first water addition stage does not necessarily require automated instrumentation to measure wheat moisture on-line and calculate the added amount. A flow meter and sensor to indicate wheat flow are sufficient. The amount of water added should be calculated by the miller. An intensive mixer for efficient water distribution on the wheat surface is usually beneficial. The second stage of water addition should have the instrumentation necessary to measure wheat moisture on-line and add the exact amount of water to the desired level. It is recommended that up to 0.5% of the water be added to the conditioned wheat just before a surge bin with the capacity to accommodate 15–20-min of tempering before the wheat is fed to the first break. In general, to accommodate the elasticity of the bran and secure the appropriate friability of the endosperm the moisture content of the bran should be ≈2% higher than that of the endosperm.

First in-first out (FIFO) flow of the tempered wheat is vital to guarantee that the tempering time is adequate and uniform for all wheat kernels. Variation in tempering time caused by distorted wheat flow could affect the balance of the mill and quality of the product. In some cases although the available tempering space is sufficient for the required extended tempering time, the flow out of the bins is such that it distorts the desired time. To guarantee FIFO flow of the tempered wheat, an appropriate diameter is required for the multiple outlets. Outlet pipes with a minimum 15.24 mm (6 in.) inner diameter should be used. Bin sizes differ from mill to mill, and the miller should consider the most appropriate measures to accommodate FIFO flow of the wheat from the tempering bins.

Conditioning of wheat for milling depends on three variables: amount of water, tempering time, and temperature. One newly developed approach is the use of vibration following the water addition stage. The energy dissipated by the mechanical vibration raises the wheat temperature and affects the rate of water penetration into the wheat kernels.

Two methods are often used by mills to make decisions regarding optimization of wheat conditioning and mill adjustments. Millers can use either of these methods based on which is best suited to their mill and on the availability of testing equipment. The first method is based on the use of the meal from the first break roll stand in a commercial or laboratory mill that allows the production of an intermediate product. An example of such a laboratory mill is the CD2 (Tripette & Renaud Chopin, Villenueve la Garenne Cedex, France), which is not fully automated and generates intermediate material after the first grinding stage. To determine the appropriate conditioning level for a certain load of wheat, the miller test grinds a sample of conditioned wheat and sifts the meal on a laboratory sifter. The sizing, middlings, and flour fractions generated should be evaluated for weight and percent particle size distribution, ash content, and moisture. Correlating the generated values with mill performance with respect to semolina and flour extraction can give an indication of the optimum wheat conditioning for milling in a specific mill.

A second method used to determine optimal tempering time involves the use of a batch-type experimental mill. Samples should be conditioned to 16% moisture content but varied in tempering time. This method can be used to determine optimum conditioning of Desert Durum. Color is a very important factor in pasta, and millers and pasta manufacturers want the bright yellow color of the wheat to be carried over through the milling process to the semolina and then to the finished product. The following data are from a trial test using this method. Final evaluation of the results and procedure to be selected was based on semolina color. Semolina color values (measured using a Minolta CR-310 chronometer) were weighted on extraction levels and showed total cumulative L^* (brightness) values of 83.52, 82.78, 80.95, and 79.20 for 2 × 12 hr, 2 × 18 hr, 3 × 8 hr, and 2 × 4 hr of tempering, respectively. Using two stages of 18 hr of tempering resulted in higher semolina extraction, the best color, and the lowest ash content in final products. However, because of constraints in the commercial mill, the conditioning procedure was different, and water was added in two stages followed by 12 hr of tempering (24 hr total).

Milling Technology. Adjustments to milling technology for processing Desert Durum can result in semolina from which high-quality pasta can be produced. Adjustments also can result in a significantly higher return compared with conventional durum. One of the main parameters in Desert Durum milling is the surface of the grinding rolls. The larger wheat kernel size requires larger corrugations (i.e., fewer per inch or centimeter). Corrugations that are too small increase starch damage during grinding. For conventional durum, the technical specifications for grinding roll surface should start on the first break with 3.5 corrugations per cm (CPC) or 8.89

Table I. Equipment specifications for two commercial mills

Parameter	Mill 1	Mill 2
	17	15.25
	0.08	0.075
	7.2	4

Table II. Desert Durum and commercial Canadian Western Amber Durum (CWAD No. 2) wheat characteristics

Characteristic	Desert Durum (Mill 1)	CWAD No. 2 (Mill 1)	Desert Durum (Mill 2)
U.S. grade	1	1	1
Test weight (kg/hL)	80.2	79.0	83.3
Thousand-kernel weight (g, db)	51.43	45	NA[a]
Foreign material (%)	0.1	0.5	NA
Hard vitreous amber color kernels (%)	96	73.6	NA
Moisture (%)	6.1	13.1	6.9
Ash (12% mb)	1.5	NA	NA
Protein (12% mb)	13	12.8	NA
Kernel size over 7w (%)	96	51	94
Kernel size over 8w (%)	4	45	6
Kernel size over 10w (%)	0	4	0

[a] Not available.

corrugations per inch (CPI). For Desert Durum, 3.2 CPC (8.13 CPI) on the first break would perform better. Sharp-to-sharp action of the corrugations on the head breaks would generate ample sizing. The fourth and fifth breaks could be set at D:D. Corrugation spirals should start at 8% on the first break and increase to 14% depending on the grinding stage. For the front angle, corrugation angles should be between 25 and 30° and for the back angle between 60 and 65°. Rolls should be adjusted to relatively lower break releases through a 1,000-µm (No. 18 U.S. standard) sieve—20, 35, and 54% for the first, second, and third breaks, respectively. Especially in the initial grinding stages, first and second break roll configurations have a significant effect on the distribution of intermediate materials throughout the milling system. The significant relationship of first and second roll characteristics to the efficiency of grinding various kernel sizes was shown by Li and Posner (8). Modern roll stands with cassette replacement of the rolls could be beneficial when changing from hard wheat or conventional durum to Desert Durum with larger kernels. To overcome the issue of significant change in kernel size between durum and hard wheat in a swing mill, there is the option of installing an additional grinding surface (with one roll stand or two) as a parallel set to be used for the first and second breaks for hard wheat.

Advanced fine mill adjustments should be based on information generated by the distribution table and granulation curves, which indicate stock distribution and quality within the mill (7). These should be on hand in every commercial mill to provide the operator with guidelines and a starting point for mill adjustments, as well as to optimize loads, when receiving a new type of wheat.

The milling experiments described here were conducted in two commercial mills, both integrated with pasta manufacturing lines. The milling capacity of the first mill (Mill 1) was 100 t/24 hr. Mill 1 was designed by an Italian milling engineering company in the late 1980s and positioned in front of a multiple-line pasta plant. The second mill (Mill 2) was designed as a swing mill for hard wheat and durum processing by an Italian milling engineering company in 1995. It too supplied products to a pasta factory. The milling capacity of Mill 2 for durum was 200 t/24 hr and for hard wheat was 240 t/24 hr. The specific equipment dimensions for the two mills are shown in Table I.

The objective of the tests was to demonstrate the performance of Desert Durum on commercial mills. Table II lists some characteristics of the two commercial loads of Desert Durum wheat and of the conventional durum wheat tested (CWAD No. 2). The most significant characteristic of the Desert Durum was the uniformity of kernel size, which is a major contributor to its better milling quality compared with the conventional durum wheat. Laboratories and available equipment vary from one commercial plant to another. As a result, mills vary significantly in their procedures for testing and evaluating wheat and final products, and the evaluation results collected in the mills are not always comparable. Missing data are a result of differences in procedures.

To evaluate and optimize Desert Durum performance, the samples were divided into two batches each, allowing initial adjustments to be made on the first batch and additional corrections to be made on the second. This approach, collecting information on initially processed batches followed by fine adjustments on subsequent batches, could be used for any type of wheat entering the mill.

As mentioned earlier, Mill 2 was designed to process hard and durum wheats and, therefore, needed significant adjustments to the cleaning system. This was especially necessary to solve problems caused by the larger Desert Durum wheat kernels and their higher specific weight. As a result, the cleaning capacity for wheat in Mill 2 needed to be reduced by 20% from the capacity designated by the mill engineering company to achieve good removal of unmillable materials.

Wheat moisture to the first break was 17.2–17.5% in Mill 1. Break releases were adjusted to 20, 35, and 54% for the first, second, and third breaks, respectively. Because Mill 2 was a swing mill, it needed special scheduling of two tempering periods of 12 hr each. Moisture to the first break in Mill 2 fluctuated between 15.45 and 16.0% due to an undependable water adjustment apparatus and a distortion in the tempered wheat outflow from the bins.

Blends of semolina and flour were tested on the commercial pasta lines in both plants. Pasta was cooked and quality was evaluated in the laboratory of Mill 1 (AACC International Method 66-50 [1]).

The testing equipment and procedures used for research often are not available in commercial mills. As a result, we had to rely on former research, information, and experience in making adjustments and changes during large-scale testing. Because of the substantial differences between the two commercial mills, data from the test results presented differently and should be analyzed subjectively based on local demand.

Semolina and flour extraction rates varied between the mills based on mill characteristics and durum quality. Harder kernels generated higher percentages of semolina. The commercial amber durum wheat variety to which the samples were compared produced an extraction average of 75–77% based on total product. Larger variations in kernel distribution is one of the causes of reduced clean endosperm extraction. If wheat kernels are uniform in size, break rolls act on all kernels more evenly and generate consistent amounts of intermediate materials. Table III shows the Desert Durum milling extraction results for the two mills. The longer roll surface, larger sieving area, and ample purifier width (shown in Table I) allowed separation of a higher percentage of semolina with a lower ash content in Mill 1. Mill 2, a swing mill, was limited in its purifier sieve width and performed adequately for durum milling at the assigned capacity compared with Mill 1. The characteristics of the final products from Mill 1 are shown in Table IV.

Table III. Desert Durum milling extraction results for two commercial mills

	Mill 1		Mill 2	
Product	Particle size (µm)	Percent	Particle Size (µm)	Percent
Coarse semolina			590–335	64.42
Fine semolina				
Total semolina				64.42
Flour 1	202–0		160–0	10.38
Flour 2			160–0	2.48
Flour 3			118–0	3.05
Total semolina and flours		80		80.33
Bran		20		19.67
Total products		100		100

Table IV. Proximate analysis results for Desert Durum products from Mill 1

Characteristic[a]	Coarse Semolina	Fine Semolina	Flour	Coarse Bran	Fine Bran

[a] L^*: brightness; a^*: +, redness and –, greenness; b^*: +, yellowness and –, blueness.

Final Durum Wheat Products

Significant differences in product extraction, semolina, flour, and pasta quality from Desert Durum were found in both mills. Results for Desert Durum from both mills were compared with commercial amber durum wheat from the same source. Mill 1 used the Desert Durum semolina and flour produced for pasta production, whereas Mill 2 used a blend of 76% that included the Desert Durum semolina and Flour 1 and Flour 2. A higher flour yield was produced in Mill 2 because it is a swing mill with shallow break corrugations (angles 25–40° for the front angle and 70° for the back angle). The color of the pasta produced from Desert Durum processed in Mill 1 was compared with the commercial amber durum variety (CWAD No. 2) processed in the same mill. The L^*, a^*, b^* values for Desert Durum pasta were 52.19, 3.55, and 63.65, respectively, whereas the values for CWAD No. 2 pasta were 44.51, 2.74, and 64.4, respectively.

Mill 2 produced a blend for high-quality pasta from Desert Durum semolina and two flours (Flour 1 and Flour 2). A third flour (Flour 3) was diverted for other uses. Although Mill 2 did not have an instrument to determine color values, experienced milling staff commented that Desert Durum semolina color was significantly better than had been previously produced in the mill for CWAD No. 2.

Cooking is one of the most important tests conducted on pasta. Results for pasta manufactured in Mill 1 showed that the pasta made from Desert Durum had 7.1% less loss than the pasta produced from the CWAD No. 2 durum wheat. The characteristic strong gluten content of Desert Durum is an additional advantage. Recognizing this advantage, pasta manufacturers use a blend of Desert Durum flour or semolina and hard wheat flour to produce high-quality pasta. The results of our tests showed that blended hard wheat flour and Desert Durum fine semolina improved pasta cooking tolerance compared with pasta from a blend of hard wheat flour and a commercial durum wheat variety (CWAD No. 2). The improved cooking tolerance gained with the use of Desert Durum is of significant value for pastas cooked at higher elevations, where the water boiling point is lower and pasta requires longer cooking.

Summary

Millers and pasta producers outside the United States who are aware of its advantages are using Desert Durum to produce high-quality semolina and pasta products. Although it requires some adjustments in durum milling process parameters, with relatively few changes mill operators can adjust their milling processes to produce Desert Durum products with high quality and economic value. Wheat cleaning, tempering time, and roll corrugation are the main parameters that should be evaluated and adjusted to meet the specific demands of Desert Durum product applications. Detailed mill analysis, including construction of a distribution table and granulation curves for the leading stages in the mill, should be performed and used to guide millers in making necessary adjustments to optimize Desert Durum processing.

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