Durum wheat breeding and quality improvement at CIMMYT Mexico

Abdalla O.S., Peña R.J., Autrique J.E., Nachit M.

in

Di Fonzo N. (ed.), Kaan F. (ed.), Nachit M. (ed.).
Durum wheat quality in the Mediterranean region

Zaragoza : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 22

1995
pages 133-141

Durum wheat breeding and quality improvement at CIMMYT Mexico

O.S. ABDALLA
R.J. PEÑA
J.E. AUTRIQUE
M.M. NACHIT
CIMMYT
MEXICO D.F.
MEXICO

SUMMARY - Through mega-environment directed breeding, the Mexico-based CIMMYT Durum Wheat (DW) Programme has been able to provide national programmes with high-yielding, management-responsive and input-efficient germplasm. The ultimate goal of the programme is to simultaneously increase yield and improve end-use grain quality of durums in developing countries. In this paper, priority quality traits of grain size, vitreousness, gluten strength and yellow pigment content are discussed, selection for quality characters is described and recent advances made in improving DW quality at CIMMYT Mexico are reviewed. Results indicate high gluten strength levels are currently available in CIMMYT's germplasm. However, more efforts are needed to enhance the level of yellow pigment concentration.

Key words: Durum wheat, mega-environment, quality characteristics, SDS-sedimentation, gluten strength, yellow pigment concentration.

RESUME *- "Sélection du blé dur et amélioration de la qualité au CIMMYT, Mexique". A travers l'amélioration dirigée sur les méga-environnements, le programme blé dur du CIMMYT basé au Mexique a été capable de mettre à la disposition de programmes nationaux un germoplasme à haut rendement, répondant aux techniques culturales et utilisant efficacement les ressources. L'objectif final du programme est simultanément l'augmentation du rendement et l'amélioration de la qualité du grain des blés durs dans les pays en développement. Dans le présent article, on discute des caractéristiques prioritaires pour la qualité comme la taille du grain, la vitrosité, la force du gluten et la teneur en pigment jaune, on décrit la sélection des caractères de qualité et on passe en revue les progrès récents obtenus dans l'amélioration du blé dur au CIMMYT au Mexique. Les résultats indiquent que des valeurs élevées de la force du gluten sont actuellement disponibles dans le matériel génétique du CIMMYT. Cependant, des efforts sont encore nécessaires pour augmenter le niveau de la concentration en pigment jaune.*

Mots-clés : *Blé dur, méga-environnement, caractères de qualité, sédimentation SDS, force en gluten, concentration en pigment jaune.*

Durum breeding at CIMMYT

Durum wheat, *Triticum durum* Desf., is cultivated on approximately 17 million hectares worldwide. Its production is concentrated in the Middle East, North Africa, the Asian Subcontinent and Mediterranean Europe. Other production areas include Ethiopia, Argentina, Chile and the Andean region of South America as well as Mexico, the United States and Canada.

At CIMMYT, intensive improvement of durum has been conducted for a little more than two decades. The main goal of the CIMMYT Durum Programme is to assist developing countries increase durum productivity by supplying high yielding, widely adapted, disease resistant germplasm with good end-use quality characteristics. To achieve these objectives, the CIMMYT Durum Programme directs its breeding efforts and addresses production constraints encountered in the mega-environments shown in Table 1 (Abdalla *et al.*, 1992).

Through a dynamic breeding programme, involving directed and broadly based crossing programme, shuttle breeding and multilocational testing, CIMMYT has been able to provide developing countries with high yielding, management-responsive and input-efficient germplasm. Such basic germplasm has been utilized, and released as varieties in many parts of the world as shown in Table 2 where about 63% of the varieties released in developing countries during 1966-1990 are CIMMYT or CIMMYT/ICARDA crosses (Byerlee, 1992).

Table 1. Durum wheat mega-environment (Abdalla *et al.*, 1992)

Mega-environment (ME)/Climate	Major diseases	Representative locations
Spring type		
ME1 irrigated, low rainfall, temperate	LR, YR, PM, SR	Yaqui Valley (Mexico), (Pakistan), Gangetic Valley (India), Nile Valley (Egypt)
ME2 high rainfall, temperate	LR, ST, YR, PM, SR, BYD, Bact, Scab	Mediterranean basin, Southern cone, Andean highlands, East African highlands
M4A low rainfall, temperate, winter rain	ST, YR, LR	Aleppo (Syria), Settat (Morocco)
C low rainfall, warm	SR	Indore (India)
Winter/facultative type		
ME6B moderate cold, low rainfall	Bunts	Diyarbakir (Turkey)

YR = Stripe rust (*Puccinia striiformis*)
LR = Leaf rust (*Puccinia recondita*)
SR = Stem rust (*Puccinia graminis*)
ST = *Septoria tritici* (*Mycosphaerella graminicola*)
Scab = *Fusarium* spp.
PM = Powdery mildew (*Erysiphe graminis*)
BYD = Barley yellow dwarf luteovirus
Bact = *Xanthomonas translucens*

Table 2. Durum wheat varietal releases in developing countries (period 1966-1990) (Byerlee, 1992)

Region	Releases	
	Total	CIMMYT/ICARDA and CIMMYT crosses
Sub-Saharan Africa	7	2
Wana	80	50
Asia	21	8
Latin America	27	25
Total	135	85

Durum wheat quality

Durum wheat (DW) grain is used to prepare various products in different parts of the world. The acceptability of a new DW variety is greatly influenced by its quality characteristics. Table 3 lists the major products from DW and their quality requirements. These products generally require large vitreous kernels with high protein, good yellow pigment and strong to medium-strong gluten. Thus, the incorporation of quality characters essential for end-use products is a major objective in DW breeding at CIMMYT.

Table 3. Durum use and quality requirements in different parts of the world (Abdalla *et al*., 1992)

Country/Region	Use	Requirement
North Africa, Europe, America, Australia	Pasta	Medium to strong gluten, high yellow pigment
North Africa	Couscous	Medium to strong gluten, high yellow pigment
Middle East	Unleavened bread	Medium to strong gluten
Near and Middle East	Bulgur	Hard grain, yellow pigment
Andean Region	Mote	Hard grain

The major quality characters in DW include: kernel size, kernel vitreousness, protein content, gluten strength and pigment concentration. In this presentation, the improvements in gluten strength and grain colour in CIMMYT germplasm are emphasized.

Kernel size is the best index for potential semolina yield. Matsuo and Dexter (1980), reported high correlation between milling yield and grain size. With large kernels a greater milling yield is expected due to a greater ratio of endosperm to bran. The 1000-kernel weight is a measure of average kernel size.

Kernel vitreousness is considered an important quality factor because it is associated with semolina yield and protein content (Matsuo, 1988; Amaya and Peña, 1992). Higher incidence of grains with yellow berry (starchy kernels) reduces semolina yield as they pulverize more readily.

Gluten strength is associated with pasta cooking quality, particularly, with respect to firmness and increased tolerance to overcooking (Matsuo and Irvine, 1970; Quick and Donnelly, 1980). γ-gliadin band 45 was found to be associated with gluten strength and γ-gliadin band 42 with gluten weakness (Damidaux *et al*., 1978; Kosmolak *et al*., 1980). It was shown that γ-gliadin bands 45 and 42 were coded for by allelic genes on chromosome 1BS (Damidaux *et al*., 1980; Joppa and Williams, 1983). Payne *et al*. (1984), showed that genes coding for γ-gliadin bands 45 and 42 were tightly linked to genes coding for glutenin subunits LMW-2 and LMW-1, respectively. They concluded that the observed associations with gluten strength are more likely caused by LMW-2 glutenin subunit than γ-gliadin band 45.

Yellow pigment: The yellow pigment is related to the carotenoid content of the endosperm. High yellow pigment is desirable in pasta products.

Selection for quality characters

Selection for grain characteristics in the CIMMYT DW Section starts in early segregating generations. Seed from F_3 and F_6 individual plants is screened and selected on the basis of seed size, shape, uniformity, kernel vitreousness and absence of yellow berry and black point. All plants with small and shrivelled seeds are discarded.

For the evaluation to gluten strength, a modified version of the SDS-Sedimentation test of Dick and Quick (1983) is currently being used at CIMMYT (Amaya and Peña, 1992). This test is conducted on whole meal for segregating populations and on flour for advance DW lines. Since the test requires only 1 g flour, large number of entries could easily be tested. Cut-offs are determined based on known strong gluten checks grown under similar conditions as the test maternal. Based on SDS-sedimentation values measured on whole meal or flour, the material is generally classified into weak, medium and strong gluten groups as shown in Table 4. Weak gluten material is generally discarded.

For the evaluation of yellow pigment in the individual plants, CIMMYT uses the standard method of the American Association of Cereal Chemists 14-50 (AACC, 1983), with the following modifications:

AACC Method 14-50	CIMMYT Wheat Quality Laboratory
Weight: 8 g sample, Add 40 ml reagent, Let stand 16-18 h. Filter through Whatman No. 1 filter paper, Determine yellow colour in clear extract	Weight: 3 g sample, 15 ml reagent, Shake 1 h, Centrifuge at 7000 rpm for 5 minutes, Determine yellow colour in clear supernatant

These modifications allow evaluation of a large number of individual plants with small amounts of seed. Only plants with a pigment content equal to or higher than that of the quality check are selected. Table 5 shows the classification of material based on yellow pigment concentration measured in whole meal or flour.

Table 4. Gluten strength and yellow pigment classification groups measured on whole meal and flour

Classification group	Whole meal	Flour
SDS-Sedimentation (ml)		
Weak gluten	<7	<10
Medium gluten	7-10	10-12
Strong gluten	>10	>12
Yellow pigment content (ppm)		
Low pigment	<5.0	<6.5
Medium pigment	5.0-7.0	6.5-8.5
High pigment	>7.0	>8.5

Table 5. Frequency of low molecular weight (LMW) glutenin subunits in DW crossing block (BV92)

LMW-GLU	Frequency Var. or Line	Example
1	6%	IMMER; SLA; CHELLE.; WAHA
2	94%	CIT-71; MEXI75; YAV79; DON87

Spaghetti processing

When lines become commercial variety candidates, a complete evaluation for spaghetti quality is performed. Samples are milled on a Brabender Quadrumat Jr. Mill; only corrugated (breaking) rolls are sued. Prior to milling, the wheat is tempered overnight to a 15.5% moisture content. The whole milling products are sifted for 7 sec on a rotomatic sifter equipped with 30 W and 100 W sieves to separate semolina from the other ground material. The "overs" on the 30 W are bran; the "throughs" on the 100 W are flour; the "middle overs" on the 100 W and "throughs" on the 30 W are semolina.

The semolina samples are processed into spaghetti using a Namad vacuum pasta extruder. The samples are processed with an absorption of 34.5% and extruded through a Teflon spaghetti die. Spaghetti is dried in an experimental pasta dryer for 18 h. During the drying period, the humidity of the dryer decreases from 100 to 70% RH while the temperature is held constant at 40°C.

Spaghetti cooking quality is evaluated at optimum (10-12 min) and overcooked (15 min) cooking times. Cooked spaghetti is evaluated for firmness and stickiness. The data are made available to the breeders so that they can define which lines to use in their crosses and which ones to discard.

Advances in quality improvement

Historically, the CIMMYT based DW programme has utilized in its crossing programme good quality sources from Italy, France, the USA and Canada despite the lack of adaptation of these sources to the main mega-environments targeted by CIMMYT (Brajcich *et al.*, 1983). Nonetheless, this effort has led to overall improved quality in CIMMYT derived germplasm. Current CIMMYT's germplasm, generally, combines high yield potential, good agronomic type, multiple disease resistance, wide adaptation as well as good end-use quality characteristics. The recent advances made in improving DW quality at CIMMYT are reflected in the progenitors utilized in crossing, the specialized durum quality nurseries (DQN) and the germplasm distributed to the national programmes and cooperators.

Table 6 shows the frequency of low molecular weight (LMW) glutenin subunits, LMW-1 and LMW-2, in the most recently analyzed DW crossing block (CBSDW-BV92). Examples of varieties or advance lines carrying the respective subunits is given. 94% of the total entries of the crossing block carry LMW-2 which is associated with strong gluten (Payne *et al.*, 1984). The remaining 6% are resistance/tolerance sources for particular diseases or stresses rather than quality. The role of HMW glutenins in quality is not well understood (MacRitchie *et al.*, 1990). However, DW crossing block exhibits great variability in high molecular weight (HMW) glutenin subunits (Table 6). Subunit 7+8 has the highest frequency (52%).

Table 6. Frequency of high molecular weight (HMW) glutenin subunits in DW crossing block (BV92)

HMW-GLU 1B	Frequency Var or line	Example
7 + 8	52%	WAHA; ALTAR 84; ACONCHI 89;
20	22%	YAV79; OMRABI-5; DON87;
6 + 8	16%	RASCON-21; DUKEM-12;
13 + 16	6%	GREEN-18; PORRON-4;
13 + 19	4%	CIT71

Fig. 1 exhibits gluten strength frequency distribution in CIMMYT's current crossing block (CBSDW-BV93) and indicates the gluten strength of known check varieties and popular crosses. Observed gluten strength based on SDS-Sedimentation values, ranged from 5.0 to 18.0 cc. The figure shows that 59% of the total entries in the crossing block have higher sedimentation values, i.e. better gluten strength than the strongest gluten cultivar "Don-87=Don Pedro-87". In contrast, the frequency distribution of yellow pigment in the current crossing block (CBSDW-BV93) shows only 4% of the lines have better pigment than "Don 87" (Fig. 2). This implies that more effort is needed to up-grade the level of yellow pigment in CIMMYT germplasm. Crossing block lines with better quality characteristics than known varieties are listed in Table 7.

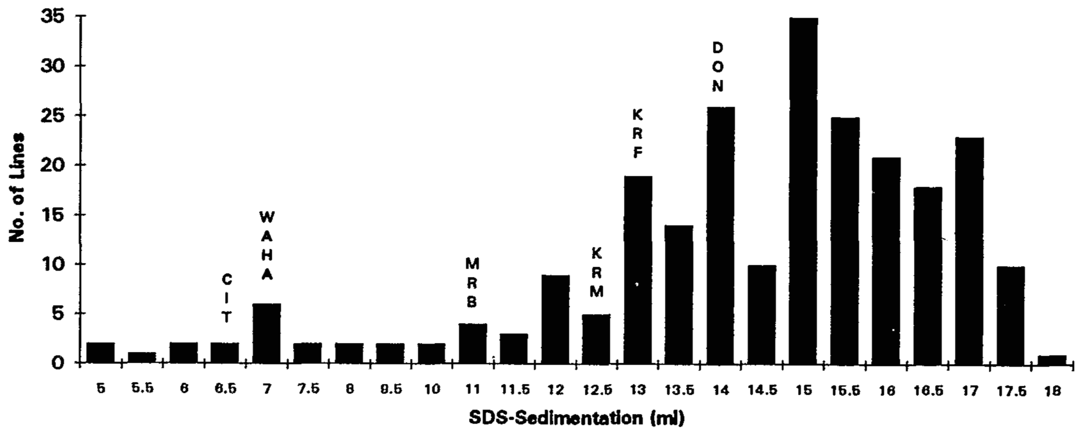

Fig. 1. Distribution of crossing block lines based on SDS-Sedimentation test. Sedimentation values are shown for some cultivars: CIT, Cocorit 71; MRB, Omrabi_5; KRM, Karim; KRF, Korifla; DON, Don Pedro 87.

Table 7. Quality characteristics of varieties and crossing block lines

	Protein (%)	SDS Sedimentation (ml)	Pigment (ppm)
Varieties			
Altar 84	13.0	14.5	8.3
Aconchi 89	13.0	15.0	9.0
Advance DW lines			
Rissa	12.4	16.5	9.2
Kitti	13.6	18.5	8.4
Ajaia	11.7	18.5	9.0
Pagalo	12.7	17.0	10.9
Charran	12.4	17.5	10.8
Yav/Auk	11.8	18.0	10.8

To enhance specific quality parameter in CIMMYT-derived germplasm, specialized durum quality nurseries (DQN) are used by Mexico-based CIMMYT DW programme. Table 8 shows the ranges and means of quality parameters of the specialized nurseries. DQN will be available to cooperators for the first time in 1994. They will be used to generate information on quality under variable environmental conditions. The quality characteristics of some advance DW lines from specialized DQN are presented in Table 9 and compared to known varieties.

In the early years of CIMMYT DW breeding programme greater emphasis was made towards increasing yield potential and broadening adaptation and stability through enhanced levels of disease resistance and stress tolerance. Lately, quality improvement has been stressed and as a result marked improvement is witnessed in the quality of germplasm distributed recently to national programmes and cooperators. Fig. 3 compares gluten strength distribution frequencies in the 20th, 23rd and 25th International Durum Screening Nursery (IDSN). These nurseries were distributed to cooperators during

1988/89 to 1993/94 seasons. The figure shows that the frequency of weak gluten has been greatly reduced over the years and that of strong gluten is increased. These results indicate that, in recent years, CIMMYT has produced and distributed a greater number of lines with superior quality to national programmes.

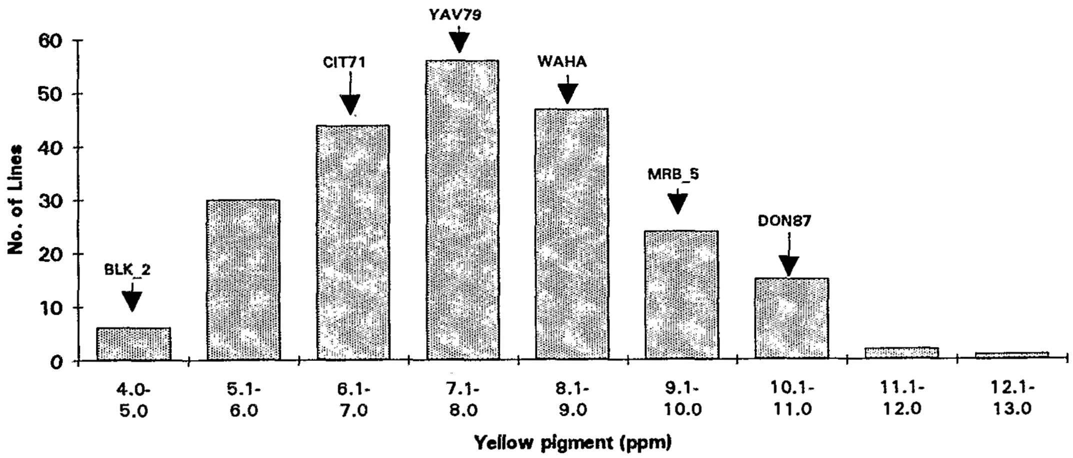

Fig. 2. Pigment distribution of crossing block lines. Pigment values are shown for some cultivars: BLK_2, Belikh 2; CIT71, Cocorit 71; YAV79, Yavaros 79; MRB_5, Omrabi 5; DON87, Don Pedro 87.

Table 8. Specialized durum wheat Quality Nurseries and their quality parameters

Nursery	Total	Protein (%)		Yellow pigment		SDS (cc)	
	No.	Range	Mean	Range	Mean	Range	Mean
PC protein	20	13.5-17.8	14.3	---	---	---	---
PC pigment	13	---	---	10.4-12.0	11.0	---	---
PC sedimentation	43	---	---	---	---	15.0-17.5	15.5
PC sedim. + pigm.	21	---	---	8.6-13.2	9.8	14.0-16.5	15.0

Table 9. Quality data for durum Quality Nurseries (DQN) and varieties of WANA Region (1992/93)

	SDS sedim. (ml)	Pigment (ppm)
DQN lines		
Green 38	16.0	9.6
Serra	16.0	10.7
Phaethon	16.5	10.2
Solga 8	16.5	10.8
Croc-1	16.0	12.3
Arlin	17.0	11.0
Varieties		
Mexi75 = Stork'S'	14.0	8.6
Yav79 = Bittern'S'	12.5	7.5
Waha	7.0	8.6
Belikh 2	13.5	5.0
Korifla	13.0	7.2

Conclusions

Through the years Mexico-based CIMMYT DW breeding programme has been able to provide national programmes with high-yielding, management-responsive and input-efficient germplasm. The ultimate goal is to simultaneously increase yield and improve end-use grain quality of durums in developing countries. With observed increases in productivity and the approach of self-sufficiency, quality is expected to be, more than ever, an important consideration in germplasm acceptability. CIMMYT efforts in this area are expected to expand. Currently, acceptable gluten strength levels are available in CIMMYT germplasm. However, more efforts are needed to enhance the level of yellow pigment concentration in CIMMYT- derived germplasm.

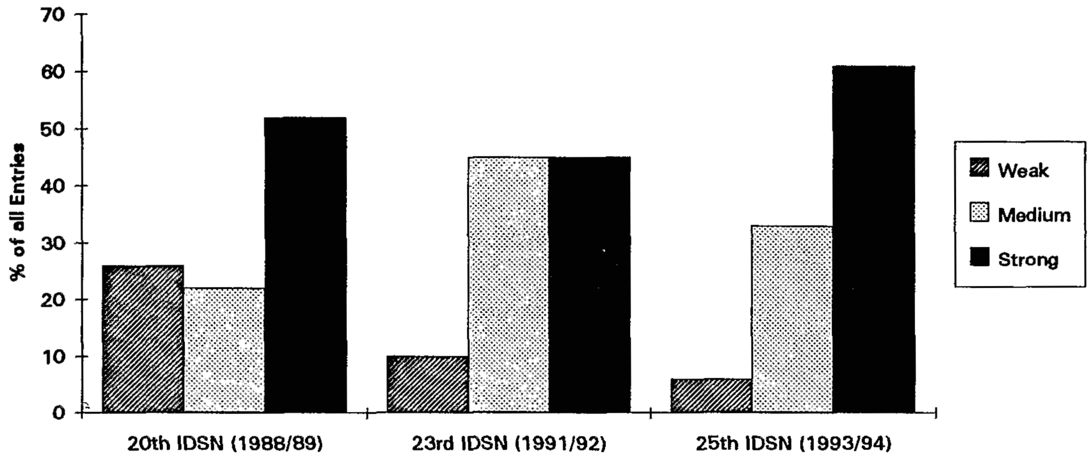

Fig. 3. Quality improvement in CIMMYT germplasm looked in three different International Durum Screening Nurseries (IDSN).

References

AACC (1983). *Approved Methods of the American Association of Cereal Chemists.* St. Paul, Minnesota.

Abdalla, O., Dieseth, J.A. and Singh, R.P. (1992). Breeding durum wheat at CIMMYT. In: *Durum Wheats: Challenges and Opportunities*, Wheat Special Report No. 9, Rajaram, S., Saari E.E. and Hettel, G.P. (eds) CIMMYT, Mexico DF, pp. 1-13.

Amaya, A. and Peña, R.J. (1992). Utilization and quality of durum wheat. In: *Durum Wheats: Challenges and Opportunities*, Wheat Special Report No. 9, Rajaram, S., Saari, E.E. and Hettel, G.P. (eds) CIMMYT, Mexico DF, pp. 166-170.

Brajcich, G.P., Vázquez, G.G. and Pfeiffer, W.H. (1983). Durum wheat. In: *CIMMYT Report on Wheat Improvement 1983-1985.* CIMMYT, Mexico DF, pp. 32-47.

Byerlee, D. (1992). Impact of durum wheat breeding in developing countries: A dilemma for the future. In *Durum Wheats: Challenges and Opportunities*, Wheat Special Report No. 9, Rajaram, S., Saari E.E. and Hettel, G.P. (eds) CIMMYT, Mexico DF, pp. 28-43.

Damidaux, R., Autran, J.C., Grignac, P. and Feillet, P. (1978). Mise in évidence de relation applicable en sélection entre l'electrophoregramme des gliadines et les propriétés viscoélastiques du gluten de *Triticum durum* Desf. *C.R. Hebd. Seances Acad. Sci.*, Ser. D, 287: 701-704.

Damidaux, R, Autran, J.C., Grignac, P. and Feillet, P. (1980). Déterminisme génétique des constituants gliadines de *Triticum durum* Desf. associes a la qualité culinaire intrinsèque des variétés. *Compte.*

Rendu Acad. Sci. Paris, Ser. D, 291: 585-588.

Dick, J.W. and Quick, J.S. (1983). A modified screening test for rapid estimation of gluten strength early generation durum wheat breeding lines. *Cereal Chem.*, 60: 315.

Joppa, L.R. and Williams, N.D. (1983). Chromosomal location of genes for gliadin polypeptides in durum wheat *Triticum turgidum* L. *Theor. Appl. Genet.*, 64: 289-293.

Kosmolak, F.G., Dexter, J.E., Matsuo, R.R. and Marchylo, B.A. (1980). A relationship between durum wheat quality and gliadin electrophoreograms. *Can. J. Plant Sci.*, 60: 427-432.

MacRitchie, F., du Cros, D.L. and Wrigley, C.W. (1990). Flour polypeptides related to wheat quality. In: *Advances in Cereal Sci. and Tech.*, Pomeranz, Y. (ed.) AACC, St. Paul, Minnesota 10: 79-145.

Matsuo, R.R. (1988). Evaluation of durum wheat, semolina and pasta in Canada. In: *Durum Wheat: Chemistry and Technology*, Fabrini, G. and Lintas, C. (eds) AACC, St. Paul, Minnesota.

Matsuo, R.R. and Dexter, J.E. (1980). Relationship between some durum wheat physical characteristics and semolina milling properties. *Can. J. Plant Sci.*, 60: 49-53.

Matsuo, R.R. and Irvine, G.N. (1970). Effect of gluten on the cooking quality of spaghetti. *Cereal Chem.*, 47: 173-180.

Payne, I.P., Jackson, E.A. and Holt, L.M. (1984). The association between γ-gliadin 45 and gluten strength in durum wheat varieties: A direct causal effect or the result of genetic linkage? *J. Cereal Sci.*, 2: 73-81.

Quick, J.S. and Donnelly, B.J. (1980). A rapid test for estimating durum wheat gluten quality. *Crop Sci.*, 20: 816-818.