SURVEY ON OVERCOOKING RESISTANCE OF ITALIAN AND TUNISIAN SPAGHETTI

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ABSTRACT

Texture properties of cooked pasta are generally recognized as the most important parameters in evaluating its overall quality. Published data concerning overcooking performances, however, are very scarce. To this end, a pasta shear test was performed at suggested cooking time and at 5, 10 and 20 min of overcooking. The most important spaghetti brands from Italy and Tunisia, the largest world pasta producers and consumers, were tested. The maximum cutting force at cooking times varies from 0.122 to 0.271 N/mm^2 and the total work to cut from 0.113 to 0.291 mJ/mm^2. Very important for consumers and foodservices are the differences for overcooking resistance among the brands. In fact, the maximum cutting force can reach up to 0.042 N/mm^2 and the total work to cut up to 0.048 mJ/mm^2, also with an overcooking time of 20 min. Generally, the highest values were shown by some Italian spaghetti, although Tunisian spaghetti and some low-price Italian products have the lowest values. For a simple evaluation of overcooking resistance, a new index was also proposed.

PRACTICAL APPLICATIONS

Published data concerning cooking and, above all, overcooking performances of pasta are very scarce or absent. Generally, these data are obtained according to the American Association of Cereal Chemists method, but quality evaluation of pasta by consumers is performed only at the time suggested by producers. In this work, a pasta shear test was then performed at these

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suggested cooking times and at 5, 10 and 20 min of overcooking. Obtained results showed large differences on overcooking resistance among the brands. Also, a new overcooking index was defined in the work. This index can be very interesting for consumers and, above all, for foodservices, such as catering or school lunches, where course consumption is carried out a long time after it is cooked, thereby overcooking the product.

INTRODUCTION

Italy is the most important world producer (3.1 Mt/year) and consumer (28 kg/per capita/year) of pasta, and Italian pasta is widely accepted as the most desirable product in terms of color, flavor and textural properties.

Although Italian pasta is regarded as the international quality-benchmarking standard, published data concerning the textural properties and cooking performances of this product are very scarce (Sgrulletta and Stefanis 1995; Stefanis and Sgrulletta 1997; Wood *et al.* 2001).

From a literature survey, it appears that textural properties of cooked pasta are generally recognized as the most important parameters in evaluating its overall quality. This is expressed in terms of stickiness, firmness, cooking and overcooking tolerance, water absorption, degree of swelling and loss of solids in the cooking water (Matsuo *et al.* 1972; Dexter *et al.* 1985; D'Egidio *et al.* 1990; Novaro *et al.* 1993; Del Nobile and Massera 2000; Dziki and Laskowski 2005; Martinez *et al.* 2007).

These properties are due to the raw materials used and drying conditions applied. Overall quality of cooked pasta can be linked then to the producer and his production technology if the same cooking conditions are used. These include type of water, salt concentration, ratio of water to pasta, cooking temperature and method of draining cooked pasta (Dexter and Matsuo 1979; D'Egidio *et al.* 1990; Grant *et al.* 1993; Malcolmson *et al.* 1993; Debbouz and Doetkott 1996; Güler *et al.* 2002; Cuq *et al.* 2003; Sozer and Kaya 2003; Zweifel *et al.* 2003; Del Nobile *et al.* 2005; Dziki and Laskowski 2005; Gianibelli *et al.* 2005; Baiano *et al.* 2006; Sozer *et al.* 2007).

Ideally, cooked pasta should be firm, resilient and nonsticky and these parameters could be determined by instrumental methods or by a sensory panel. However, taste panel assessments are time-consuming, require a relatively large sample size and high costs and are impractical for large numbers of samples.

A number of authors have, therefore, described successful chemical and instrumental methods for measuring cooking quality that are more standardized and reproducible (Matsuo and Irvine 1969, 1971; Voisey and Larmond 1973; D'Egidio *et al.* 1978; Matsuo *et al.* 1992; Feng and Seib 1994; Sissons *et al.* 2005). Generally, these studies have been performed with spaghetti as their regular cylindrical shape is relatively easy to model mathematically. Standardized methods for the measurement of pasta-cooking quality were also defined by the American Association of Cereal Chemists (AACC) with respect to firmness (AACC 2000) and by the International Association for Cereal Science and Technology (ICC), with respect to total organic matter or TOM (ICC 1992).

Studies about the overcooking resistance of pasta and the changes on their textural characteristics due to overcooking are scarce (Del Nobile *et al.* 2003; Dziki and Laskowski 2005; Martinez *et al.* 2007). These indications are very interesting for consumers and, above all, for foodservices such as catering or school lunches, where course consumption is carried out long after cooking. During this time, the high temperatures used to preserve courses can cause product overcooking.

The aim of this work was then to define overcooking resistance of a large number of spaghetti from Italy and Tunisia by shear test. These two countries along with Venezuela (13 kg/pro capita/year) are the world's highest consumers of pasta. Texture analysis of pasta was generally performed according to AACC 16-50 method (AACC 2000) where the white central core disappears if strands are squashed between two plexiglass plates. In this work, the cooking times suggested by producers were used. Afterward, the real cooking conditions applied by consumers were utilized and the overcooking resistance was considered as a quality parameter of pasta.

MATERIALS AND METHODS

Samples

Fifteen Italian spaghetti types (long form straight pasta strands; 1.50–2.00 mm diameter) from all the most important Italian brands covering over 99% of the Italian spaghetti market were purchased in Italian stores. Brands included were: Agnesi, Antonio Amato, Barilla, Buitoni, De Cecco, COOP, Divella, La Molisana, MarcaSi, Molino Molisana, Rey, Setteducati, SMA, Del Verde, Voiello. Three packages from different lots were analyzed for each product.

Four Tunisian spaghetti types (long form straight pasta strands; 1.50–1.80 mm diameter) were supplied directly by the main local brands (Randa, La Rose Blanche, Epi d'Or, Spiga). Also, in this case for each product, three packages from different lots were examined. All examined products were made from semolina with no addition of eggs.

Pasta strands (25 g of product; 10 cm in length) were cooked in distilled water according to AACC 66-50 method (AACC 2000). When cooking times were reached, samples were drained, rinsed with fresh water for 30 s, drained and placed in 500 mL of distilled water at room temperature for 1 min before analysis.

The first cooking time applied is that reported by producer (T_0). When an interval of times was reported, the mean value of these values was used. Each sample was also subjected at 5 (T_{0+5}), 10 (T_{0+10}) and 20 (T_{0+20}) minutes of overcooking and a fixed cooking time of 13 min (T_{13}). This last time was used according to ICC 153 method (ICC 1992) for TOM evaluation.

Pasta Diameter and Section Area

Fifteen strands of dry, uncooked spaghetti (five strands per lot) were chosen at random; the midstrand diameter was measured in millimeters with digital calipers and the mean diameter was calculated.

For cooked spaghetti, a slice was obtained from each strand. The side of each slice was taken with the scanner Epson Perfection 1650 (Seiko-Epson Corporation, Nagano, Japan) at 12,800 dpi in black and white photo with a 16-bit resolution. Diameter and area were determined with the Sigma Scan Pro rel. 5.0 software (Systat Software, Richmond, CA). For each production lot, three analyses of five spaghetti strands were performed and mean values were calculated.

The difference between diameter of cooked and uncooked spaghetti at (T_{13}) related to diameter of uncooked spaghetti was used to define the hydration capacity (HC) of products. HC was determined with the formula $HC = [(D_c - D_u)/D_u] \times 100$ where D_c is the diameter of cooked spaghetti at standard time of 13 min (T_{13}) and D_u is the diameter of uncooked spaghetti (Wood *et al.* 2001).

Texture Analysis

Texture analysis was performed only for cooked spaghetti with a TAxT2i Texture Analyzer (Stable Micro Systems, Godalming, U.K.) fitted with a Perspex cutting probe of 1 mm of thickness according to AACC 66-50 method (AACC 2000). The crosshead speed was 10 mm/s; the data were acquired with a resolution of 500 Hz and a load cell of 25 kg was used. The test was performed so that the knife descended for a distance of 5 mm to stop at 0.5 mm from the base plate then returned to the start position. The base plate and knife were cleaned and dried before similarly testing the other five pasta strands. For each lot, three analyses of five spaghetti strands were performed and mean values were calculated. The cooked strands were placed on the base plate of texture analyzer, parallel without touching one another and at right angles to the cutting knife. The Texture Export Exceed software rel. 2.54 (Stable Micro

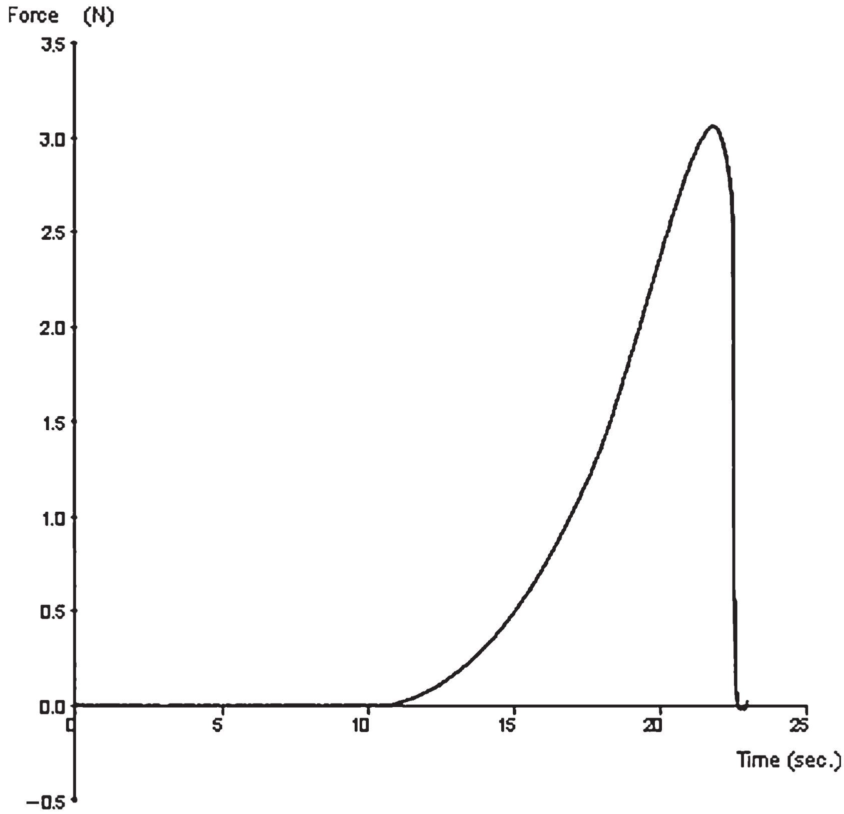

FIG. 1. AN EXAMPLE OF TYPICAL FORCE–DEFORMATION CURVE FOR SPAGHETTI

Systems, Godalming, U.K.) was used to acquire the force–time curve and to evaluate the maximum cutting force (N) and the total work to cut (mJ) (Fig. 1).

Because strand diameters of each pasta sample are different, all textural values were divided by the mean area values of each cooked pasta sample. Consequently, the maximum cutting force was reported as N/mm^2 and the total work to cut as mJ/mm^2.

Chemical Analysis

The TOM, the amount of surface material released in the water after thoroughly rinsing the cooked pasta, was determined at the standard cooking time of 13 min according to the ICC 153 method (ICC 1992). The mean values of three determinations for each lot were calculated.

TOM values of more than 2.1 g/100 g correspond to a low cooking quality. Values between 2.1 and 1.4 g/100 g correspond to a good cooking quality and values less than 1.4 g/100 g correspond to a very good cooking quality.

Statistical Analysis

Conventional statistical methods were used to calculate means and standard deviations. Analysis of variance and a multiple comparison Duncan's test were used to determine differences between spaghetti brands and were performed by STATISTICA for Windows Release 7.0 (StatSoft Inc., Tulsa, OK).

RESULTS AND DISCUSSION

Textural Parameters

Cooking times recommended by producers varied from 7 to 12 min, but generally, the suggested time was 8 min. There are no differences between Italian and Tunisian spaghetti for this parameter. In Table 1, mean values and standard deviations of maximum cutting force and total work to cut for each sample were reported. Standard deviations are generally very low and their values are lower with high overcooking times. This is due to the action of overcooking, above all, for a very long time (Dziki and Laskowski 2005; Martinez *et al.* 2007).

At suggested cooked time (T_0), the minimum mean value of cutting force (0.122 N/mm^2) was determined for sample 9T, a Tunisian product with a suggested cooking time of 10 min. The maximum mean value (0.271 N/mm^2) was determined for sample 7I, an Italian product with a suggested time of 7 min.

Between spaghetti with suggested cooking times of 7 min, sample 7I showed the highest values of cutting force and total work to cut. Also, with an overcooking of 20 min, this sample showed the highest values of cutting force and total work to cut.

Among spaghetti with a suggested cooking time of 8 min, sample 15I showed the highest values for the cutting force at (T_0). Sample 6I, however, showed at the same time the highest values for the total work. These samples highlighted different resistance to overcooking and the product 15I has the lowest value for cutting force at (T_{0+20}) time.

For samples with 9, 10 and 12 min suggested cooking time, the highest values of cutting force and work to cut are shown by products 1I, 8I and 4I, respectively. Moreover, resistance to overcooking varied and the highest values of texture parameters at 20 min of overcooking were shown by products 1I, 18I and 5I, respectively.

The cutting force and the total work to cut decrease with overcooking. Nevertheless, each sample showed a different trend according to differences of raw materials and production technology (D'Egidio *et al.* 1990; Wood *et al.* 2001; Cuq *et al.* 2003; Del Nobile *et al.* 2003; Baiano *et al.* 2006). Most decreases of cutting force and total work to cut were highlighted for all spaghetti samples between (T_0) and (T_{0+5}) times and between (T_{0+10}) and (T_{0+20}) times. Generally, between (T_{0+5}) and (T_{0+10}) times, the mean values of these textural parameters were constant.

TABLE 1.
FIRMNESS VALUES DETERMINED FOR THE ITALIAN (I) AND THE TUNISIAN (T) SPAGHETTI AT DIFFERENT COOKING AND OVERCOOKING TIMES AND RESULTS OF VARIANCE ANALYSIS AND DUNCAN'S TEST

Product	Suggested cooking time (T_0)	Maximum cutting force (N/mm^2)							
		T_0		T_{0+5}		T_{0+10}		T_{0+20}	
		X	σ	X	σ	X	σ	X	σ
2I	7′	0.180	0.0120	0.115	0.0040	0.089	0.0030	0.045	0.0010
7I	7′	0.271	0.0280	0.170	0.0066	0.125	0.0043	0.069	0.0019
Significance		*		*		*		*	
3I	8′	0.201^{cd}	0.0100	0.133^{g}	0.0040	0.108^{e}	0.0010	0.055^{cd}	0.0010
6I	8′	0.217^{ef}	0.0150	0.152^{h}	0.0090	0.122^{g}	0.0020	0.068^{f}	0.0010
10I	8′	0.208^{de}	0.0135	0.117^{bc}	0.0036	0.096^{d}	0.0012	0.057^{cd}	0.0009
11I	8′	0.170^{b}	0.0065	0.118^{cd}	0.0056	0.088^{c}	0.0032	0.047^{a}	0.0008
12T	8′	0.148^{a}	0.0055	0.114^{b}	0.0013	0.077^{a}	0.0031	0.050^{b}	0.0015
13I	8′	0.193^{c}	0.0173	0.121^{de}	0.0034	0.116^{f}	0.0004	0.057^{d}	0.0040
15I	8′	0.225^{f}	0.0090	0.126^{ef}	0.0034	0.099^{d}	0.0030	0.054^{c}	0.0010
16I	8′	0.180^{b}	0.0161	0.106^{a}	0.0035	0.085^{b}	0.0017	0.049^{ab}	0.0014
19I	8′	0.176^{b}	0.0123	0.132^{fg}	0.0032	0.098^{d}	0.0012	0.060^{e}	0.0009
Significance		*		*		*		*	
1I	9′	0.157	0.0070	0.098	0.0030	0.088	0.0030	0.055	0.0010
14T	9′	0.139	0.0039	0.107	0.0027	0.088	0.0023	0.048	0.0014
Significance		*		*		ns		*	
8I	10′	0.203^{d}	0.0082	0.140^{c}	0.0023	0.095^{c}	0.0017	0.059^{c}	0.0014
9T	10′	0.122^{a}	0.0072	0.095^{a}	0.0040	0.070^{a}	0.0032	0.042^{a}	0.0023
17T	10′	0.148^{b}	0.0084	0.113^{b}	0.0027	0.079^{b}	0.0021	0.047^{b}	0.0013
18I	10′	0.173^{c}	0.0092	0.150^{d}	0.0029	0.093^{c}	0.0013	0.061^{c}	0.0034
Significance		*		*		*		*	
4I	12′	0.248	0.0160	0.143	0.0070	0.111	0.0020	0.068	0.0010
5I	12′	0.166	0.0130	0.114	0.0040	0.101	0.0030	0.064	0.0040
Significance		*		*		*		ns	

Product	Suggested cooking time (T_0)	Total work to cut (mJ/mm^2)							
		T_0		T_{0+5}		T_{0+10}		T_{0+20}	
		X	σ	X	σ	X	σ	X	σ
2I	7′	0.141	0.0024	0.129	0.0034	0.117	0.0033	0.048	0.0011
7I	7′	0.248	0.0096	0.186	0.0033	0.173	0.0012	0.081	0.0028
Significance		*		*		*		*	
3I	8′	0.194^{c}	0.0075	0.156^{e}	0.0046	0.144^{d}	0.0036	0.062^{b}	0.0018
6I	8′	0.267^{g}	0.0062	0.199^{f}	0.0080	0.186^{f}	0.0043	0.090^{d}	0.0031
10I	8′	0.256^{f}	0.0055	0.148^{d}	0.0050	0.136^{c}	0.0021	0.069^{c}	0.0021
11I	8′	0.162^{b}	0.0043	0.134^{c}	0.0034	0.116^{b}	0.0038	0.055^{a}	0.0007
12T	8′	0.120^{a}	0.0055	0.113^{a}	0.0030	0.069^{a}	0.0056	0.052^{a}	0.0030
13I	8′	0.205^{d}	0.0093	0.150^{de}	0.0020	0.157^{e}	0.0051	0.063^{b}	0.0096
15I	8′	0.245^{e}	0.0099	0.153^{de}	0.0046	0.138^{c}	0.0012	0.064^{bc}	0.0028
16I	8′	0.187^{c}	0.0083	0.124^{b}	0.0032	0.114^{b}	0.0026	0.060^{b}	0.0018
19I	8′	0.167^{b}	0.0071	0.156^{e}	0.0093	0.135^{c}	0.0037	0.070^{c}	0.0005
Significance		*		*		*		*	
1I	9′	0.170	0.0030	0.118	0.0089	0.127	0.0042	0.069	0.0043
14T	9′	0.116	0.0084	0.119	0.0100	0.115	0.0034	0.053	0.0022
Significance		*		ns		*		*	
8I	10′	0.239^{c}	0.0050	0.185^{c}	0.0062	0.159^{c}	0.0034	0.084^{b}	0.0034
9T	10′	0.113^{a}	0.0065	0.112^{a}	0.0091	0.090^{a}	0.0068	0.052^{a}	0.0025
17T	10′	0.120^{a}	0.0054	0.127^{b}	0.0016	0.106^{b}	0.0023	0.056^{a}	0.0032
18I	10′	0.197^{b}	0.0153	0.192^{c}	0.0087	0.153^{c}	0.0034	0.084^{b}	0.0064
Significance		*		*		*		*	
4I	12′	0.291	0.0100	0.192	0.0061	0.172	0.0041	0.093	0.0031
5I	12′	0.217	0.0091	0.174	0.0067	0.165	0.0109	0.106	0.0051
Significance		*		*		ns		*	

* $P < 0.001$; mean values in the same column followed by different letters are significantly different at $P < 0.05$; for cooking time codes see the text.
ns, not significant; X, mean; σ, standard deviation;

TABLE 2.
ANGULAR COEFFICIENTS AND INTERCEPTS OF STRAIGHT LINES INTERPOLATING MAXIMUM CUTTING FORCE VALUES OF COOKING (T_0) AND OVERCOOKING (T_{0+5}) TIMES FOR THE ITALIAN (I) AND THE TUNISIAN (T) SPAGHETTI SAMPLES

Product	Angular coefficient for maximum cutting force (a)	Intercept (b)
1I	–0.0119	0.1574
2I	–0.0131	0.1804
3I	–0.0136	0.2010
4I	–0.0210	0.2480
5I	–0.0103	0.1656
6I	–0.0131	0.2168
7I	–0.0203	0.2712
8I	–0.0127	0.2035
9T	–0.0053	0.1216
10I	–0.0182	0.2080
11I	–0.0104	0.1697
12T	–0.0068	0.1477
13I	–0.0144	0.1927
14T	–0.0064	0.1391
15I	–0.0198	0.2255
16I	–0.0148	0.1802
17T	–0.0070	0.1480
18I	–0.0045	0.1729
19I	–0.0088	0.1764

Moreover, the greatest decreases between (T_{0+10}) and (T_{0+20}) overcooking times are shown by the products with the highest suggested cooking time. Consequently, they had the greatest decrease of product firmness.

These relations between overcooking time and firmness are very important from the foodservice or the consumer's point of view. Firmness is lost in the first 5 min of overcooking, while in the next 5 min, there are no other losses, so product firmness is generally constant.

To highlight the differences among spaghetti samples firmness in the first 5 min of overcooking, the straight line equations $y = ax + b$ between cutting force values at (T_0) and (T_{0+5}) for each sample were calculated. In this equation, the cutting force value was y and with $a = 0$, the b coefficient represented the mean value of cutting force at (T_0). The lower the a value is, the smaller is the resistance to overcooking and vice versa (Table 2). The highest value of angular coefficient was computed for sample 4I (–0.0210). This sample showed the lowest resistance to overcooking, although sample 18I showed the highest resistance to overcooking with the lowest value for angular coefficient (–0.0045). Tunisian spaghetti generally has low angular coefficients; hence, these products have a low firmness at (T_0) but tolerate overcooking better than some Italian products. No relationships can be highlighted between this parameter and the (T_0) cooking time; thus, the angular coefficient could be used as quality parameter and resistance index to overcooking.

TOM

The TOM values determined for each sample at the cooking time of 13 min are summarized in Table 3. Also in Table 3, maximum cutting force and total work to cut values determined at the cooking time of 13 min are reported. Variance analysis for TOM and textural parameters highlighted

TABLE 3.
TOTAL ORGANIC MATTER (TOM; g STARCH/g DRY PASTA), MAXIMUM CUTTING FORCE AND TOTAL WORK TO CUT VALUES OF THE ITALIAN (I) AND TUNISIAN (T) SPAGHETTI AT THE STANDARD COOKING TIME OF 13 MIN

Product	TOM		Maximum cutting force (N/mm^2)		Total work to cut (mJ/mm^2)	
	Mean	Cooking quality	X	σ	X	σ
1I	2.20^{e}	Low	0.116^{e}	0.0027	0.1152^{ef}	0.0056
2I	2.79^{l}	Low	0.101^{bc}	0.0032	0.0900^{b}	0.0026
3I	1.94^{d}	Good	0.117^{e}	0.0022	0.1066^{de}	0.0052
4I	1.56^{a}	Good	0.154^{i}	0.0055	0.1687^{i}	0.0055
5I	1.49^{a}	Good	0.150^{hi}	0.0068	0.1887^{l}	0.0091
6I	1.80^{c}	Good	0.143^{gh}	0.0036	0.1507^{h}	0.0079
7I	1.71^{b}	Good	0.140^{g}	0.0033	0.1320^{g}	0.0040
8I	1.83^{c}	Good	0.158^{i}	0.0046	0.1661^{i}	0.0091
9T	2.68^{i}	Low	0.083^{a}	0.0040	0.0754^{a}	0.0038
10I	2.53^{gh}	Low	0.114^{de}	0.0042	0.1140^{ef}	0.0035
11I	2.88^{m}	Low	0.107^{cd}	0.0034	0.0950^{bc}	0.0024
12T	2.68^{i}	Low	0.098^{b}	0.0016	0.0797^{a}	0.0033
13I	2.14^{e}	Low	0.118^{e}	0.0040	0.1093^{def}	0.0046
14T	2.41^{f}	Low	0.100^{bc}	0.0036	0.0849^{ab}	0.0047
15I	2.48^{fgh}	Low	0.113^{de}	0.0024	0.1131^{ef}	0.0021
16I	2.44^{fg}	Low	0.102^{bc}	0.0043	0.0948^{bc}	0.0052
17T	2.45^{fg}	low	0.120^{e}	0.0089	0.1013^{de}	0.0025
18I	1.55^{a}	Good	0.147^{gh}	0.0156	0.1472^{h}	0.0223
19I	2.55^{h}	Low	0.132^{f}	0.0025	0.1178^{f}	0.0050
Significance	*		*		*	

* $P < 0.001$.
For each sample, the cooking evaluation according to the International Association for Cereal Science and Technology 153 was reported. Mean values in the same column followed by different letters are significantly different ($P \geq 0.05$).
X, mean; σ, standard deviation.

a high variability between spaghetti samples. These differences could be explained with the degree of starch damage caused by overly intensive grain grinding during milling (Matsuo and Dexter 1980; Dziki and Laskowski 2005). All these products can be classified as "Low" or "Good" quality according to their TOM values, but there is no sample with a "Very good" cooking quality. This is very interesting as the most important brands in the Italian spaghetti market have been included in this study. The correlation analysis performed between values of TOM and textural parameters evaluated at the fixed time of 13 min highlights a negative linear correlation with the maximum cutting force ($r = -0.85$; $P < 0.01$) and the total work to cut ($r = -0.87$; $P < 0.01$). Lowest firmness is then characteristic of products with high TOM value and vice versa according to results of Dexter *et al.* (1985). Generally, with a TOM classification of "Good," the maximum cutting force is higher than 0.12 N/mm^2 and the total work to cut is higher than 0.12 mJ/mm^2. Where TOM classification is "Low," the maximum cutting force is generally lower than 0.10 N/mm^2 and the total work to cut is lower than 0.10 mJ/mm^2.

HC

In Table 4, the diameters of uncooked and cooked spaghetti at 13 min are reported. The diameter of uncooked products varies from 1.55 mm to 2.01 mm and increases significantly with final values between 2.55 and 3.18 mm. Correlation between diameter of raw products and their cooking time is not significant and this confirms the results obtained by Dziki and Laskowski (2005). Other factors such as the kind of raw materials and the parameters of technological process affecting cooking time of pasta are also highlighted (Dziki and Laskowski 2005). The computed HC shows a significant difference among samples, but this value does not correlate with the maximum cutting force ($r = -0.42$; $P > 0.05$), the total work to cut ($r = -0.48$; $P > 0.05$) and TOM ($r = 0.29$; $P > 0.05$) values.

Cooked spaghetti firmness is not correlated with product diameter and is generally lower with high diameters and, consequently, higher hydration values. These results are not, however, in agreement with Wood *et al.* (2001).

CONCLUSIONS

Obtained results showed that overcooking resistance of Italian and Tunisian spaghetti is very different among brands. Texture analysis can be used for a fast evaluation of this quality parameter as correlated with consumer evaluations highlighted by other authors. As textural parameters also showed a negative correlation with TOM, it could be possible to replace this complex

TABLE 4.
DIAMETERS OF UNCOOKED AND COOKED ITALIAN (I) AND TUNISIAN (T) SPAGHETTI AND THEIR HYDRATION CAPACITY

Product	Pasta diameter				Hydration capacity (%)	
	Uncooked (mm)		Cooked (mm)			
	X	σ	X	σ	X	σ
1I	1.76[h]	0.021	2.97[h]	0.039	69.02[fg]	2.67
2I	1.69[de]	0.027	2.70[c]	0.041	60.43[abcd]	2.48
3I	1.71[ef]	0.021	2.82[fg]	0.050	65.07[def]	2.46
4I	1.88[l]	0.028	3.04[i]	0.032	61.50[bcd]	3.42
5I	2.01[n]	0.031	3.18[l]	0.048	58.69[abc]	4.19
6I	1.90[lm]	0.014	3.07[i]	0.041	61.73[bcde]	2.59
7I	1.75[gh]	0.013	2.75[de]	0.057	57.65[ab]	3.31
8I	1.92[m]	0.022	3.04[i]	0.074	58.39[ab]	4.55
9T	1.60[b]	0.037	2.75[d]	0.036	71.67[g]	4.82
10I	1.76[h]	0.040	2.94[h]	0.053	67.55[fg]	7.34
11I	1.63[c]	0.011	2.73[cd]	0.042	67.46[fg]	3.02
12T	1.55[a]	0.020	2.65[b]	0.048	71.07[g]	4.56
13I	1.74[gh]	0.042	2.79[ef]	0.046	60.22[abcd]	4.81
14T	1.62[bc]	0.033	2.70[c]	0.024	67.05[efg]	3.61
15I	1.73[fg]	0.027	2.83[g]	0.051	64.05[cdef]	5.04
16I	1.68[d]	0.022	2.77[de]	0.061	65.00[def]	5.10
17T	1.61[bc]	0.061	2.55[a]	0.032	58.58[abc]	4.72
18I	1.80[i]	0.016	2.97[h]	0.034	61.72[def]	3.26
19I	1.70[def]	0.016	2.64[b]	0.040	55.38[a]	3.87
Significance	*		*		*	

* $P < 0.001$; mean values in the same column followed by different letters are significantly different at $P < 0.05$). Cooking time is 13 min.
X, mean; σ, standard deviation.

and time-consuming analysis with a fast, simple and more complete texture analysis. A new index for the evaluation of overcooking resistance of spaghetti was also defined in this work. It is represented by the angular coefficient of the straight line. This is calculated for the maximum cutting force values determined at the suggested cooking time and the values at 5 min overcooking. This index, if reported by producers, will be used by consumers for an evaluation of product resistance to overcooking.

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