Combined Effect of Protein Content and High-Temperature Drying Systems on Pasta Cooking Quality[1]

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ABSTRACT

Cereal Chem. 70(6):716–719

The suitability of the equation proposed previously to predict cooking quality of pasta dried at 80°C was verified on two sets of samples of Italian durum wheats grown during 1989 and 1990. The 1987 sample set used to define the predictive equation was considered as a reference set. Protein content and gluten quality were measured on grain samples. Cooking quality of pasta was evaluated as organoleptic judgment (OJ) values to measure a combination of stickiness, bulkiness, and firmness. The 1989 and 1990 pasta samples, dried with a diagram at high temperature (90°C) different from that applied to the reference set (80°C), were characterized by a higher protein content. At 90°C, the OJ observed values were underestimated by the 1987 predictive equation. A multiphase regression model with two straight lines was applied on the hypothesis of an interaction between a higher protein content and a higher drying temperature. This model allowed the change of the slope between the two regression lines to be detected and the abscissa value (14% protein content) to be determined. Therefore, two new equations were proposed to predict OJ for a 90°C pasta-drying system because of the different effect of high temperature on protein content at ±14%.

Raw material characteristics and pasta drying technologies are of primary importance in determining spaghetti cooking quality.

Many authors have established that protein content and composition are essential for obtaining a good final product with conventional low-temperature drying systems (Matweef 1966, Matsuo et al 1972, Dexter and Matsuo 1980, Feillet 1984, Autran et al 1986).

It is well known that the high-temperature drying technologies, widely used today in pasta manufacturing, have a positive influence on pasta cooking quality (Dexter et al 1981, Abecassis et al 1984, Resmini et al 1988). Among the raw material characteristics, total protein content is particularly important in these applications (Matsuo 1988, D'Egidio et al 1990, D'Egidio and Nardi 1991).

The different role of raw material characteristics in drying pasta at low and high temperatures was established in a previous work. At low temperature, protein content and gluten quality assumed the same importance in determining pasta cooking quality, whereas at high temperature, only protein content was essential. Consequently, equations were defined to predict pasta organoleptic judgment (OJ) at low- and high-temperature drying. Moreover, the high-temperature drying system (80°C) induced a consistent improvement of pasta cooking quality when protein content increased (D'Egidio et al 1990).

In this investigation, a new drying diagram at high temperature (90°C) was applied to evaluate the relative influence of protein content and drying technologies on pasta cooking quality.

MATERIALS AND METHODS

Plant Material

Two sets of durum wheat grain samples ($n = 43$ and 69), representative of main Italian varieties harvested during 1989 and 1990, were analyzed.

The 1987 data set used to define the predictive equation of pasta cooking quality at high temperature (D'Egidio et al 1990) was used as a reference set. All the samples were of pasta-making grade. The falling number values were higher than 360 sec for all the samples. The mean test weight was 83.2 kg/hl (range between 76.8 and 87.9) for 1989 and 80.4 kg/hl (range between 78.2 and 83.5) for 1990.

[1]Partially presented at the 9th International Cereal and Bread Congress (ICC), Paris, France, June 1-5, 1992.

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Laboratory Tests

Grain protein content was determined by the Kjeldahl method (N × 5.7, dmb). Gluten quality, measured by manual evaluation and alveographic procedure, was performed according to D'Egidio et al (1990) to characterize the test samples.

Technological Tests

Wheat (20 kg) was cleaned, conditioned to a water content of 16%, and left to moisten overnight. Standard milling was performed in a Buhler MLU 202 mill with three breaking and three sizing passages. The normal semolina yield reached ~70%.

The semolina was mixed with tap water to obtain a total dough-water content of 32–33%. The dough was processed into spaghetti using an experimental press (8–15 kg, industrial plant capacity). The extrusion conditions were: temperature, 50 ± 5°C; pressure, 60 ± 10 atm; and vacuum, 700 mmHg. The drying procedure applied at 90°C in the industrial plant is shown in Figure 1A.

The cooking method used 100 g of spaghetti (1.7 mm thickness, 20 cm length) in 1 L of boiling tap water (total hardness = 18 German degrees; 1 German degree = 1 g of CaO in 100 L of H_2O) without added salt. Spaghetti quality was evaluated after cooking for 13 min and draining for 9 min. All cooking tests were made in duplicate in a laboratory under controlled temperature. A third replicate was considered when the OJ difference between the duplicates was higher than 10%.

OJ was carried out by a highly trained panel of three experts. The general test conditions (order and presentation of samples, etc.) were in accordance with international standard 7304 (ISO 1985). OJ-determined values for stickiness, bulkiness, and firmness scored from 10 to 100. The score of each OJ component was the arithmetic mean of the values given by the three assessors; the final OJ value was the average of the means of stickiness, bulkiness, and firmness scores.

Statistical Analysis

The predictive equation determined on the 1987 reference set, using protein content as an independent variable (D'Egidio et al 1990), was applied to the two sets analyzed for 1989 and 1990. OJ regressed values and confidence limits were estimated; the percentages of observed OJ values lying above, within, and below the confidence belt of the 1987 regression were calculated.

The general validity of the 1987 predictive equation was controlled by two different statistical approaches: 1) the classical comparison of the linear regressions for 1989 and 1990 with the 1987 regression, and 2) the direct measure of the distance of 1989 and 1990 data from the reference regression of 1987. For the first approach, deviation from regression mean squares ($s^2\ d$), slopes (b), and elevations (a) were compared following Snedecor and Cochran (1980). For the second approach, the fit of the 1987 predictive equation to the data sets was tested by an F ratio between the deviation variance of 1989 and 1990 observed data from the 1987 regression and the residual variance of the 1987 regression.

Because the protein content and drying temperature were increased for the 1989 and 1990 samples, an interaction between these factors was hypothesized. A multiphase regression model with two straight lines (Boyd et al 1976, Jinks and Pooni 1979, Mariani et al 1983) was applied on joined data of 1989 and 1990 to control this hypothesis. The method for fitting two straight lines is described by Boyd et al (1976). By comparing the residual mean squares, the best-fitting pair of straight lines ($y_1 = a_1 + b_1 x$ and $y_2 = a_2 + b_2 x$) was selected from all possible pairs ($y \ldots y_i$ and $y_{i+1} \ldots y_n$) where i is given every value from 3 to $n - 3$. A single straight-line model was rejected in favor of the best-fitting pair only when it resulted in a significant reduction of the residual mean square and in a difference between b_1 and b_2.

The efficiency of the two-line model versus that of the linear model was measured by the F ratio between the additional reduction mean square produced by the application of the two-line model and the residual variance of linear regression (Snedecor and Cochran 1980, Mariani et al 1983). This F ratio test is analogous to that used for comparing linear with polynomial regression and the polynomials between them (Snedecor and Cochran 1980). The two-line model allowed us to identify the abscissa value corresponding to the change-over point of the slope and to determine the equations for the two-line model.

Finally, the percentages of observed OJ values lying above, within, and below the confidence belt of each straight line of the two-line model were computed.

RESULTS AND DISCUSSION

Raw material characteristics and pasta quality for the 1989 and 1990 samples are reported in Table I. They are compared with the data obtained for the 1987 reference set used to establish the predictive equation of pasta cooking quality at high drying temperatures. Protein content of 1989 and 1990 samples increased about 0.6 and 1.6% compared to that of the 1987 reference set. For gluten quality (expressed as alveograph W and manual evaluation), the 1990 sample had the best characteristics and appeared similar to the 1987 set.

OJ values of 1989 and 1990 samples were higher than those of the 1987 reference set; this was particularly true for 1990. Considering that these samples were dried with a drying diagram (Fig. 1A) at a temperature higher than that applied to the 1987 reference set (Fig. 1B), the OJ improvement could be ascribed to both different drying temperatures and increased protein content.

Protein content variability was first examined by frequency distributions (Table II). The highest frequency values shifted one class for each year to more favorable values for the 1989 and 1990 samples. It is well known that protein content assumes a primary role in determining pasta quality in high-temperature drying applications. In fact, D'Egidio et al (1990) found that protein content was statistically significant in determining OJ at high temperatures; the equation OJ = 40.50 + 2.04 (% protein) was proposed to predict pasta cooking quality.

TABLE I
Mean Value, Range of Variability, and Standard Deviation (SD) of the Quality Parameters Considered

Parameter	Sample	Mean	Range	SD
Protein content	1987	13.1	11.1–18.4	1.53
	1989	13.7	11.3–16.0	1.00
	1990	14.7	12.6–17.4	1.03
Alveograph *W*	1987	175	62–303	72.5
	1989	115	23–280	66.1
	1990	180	60–302	68.3
Manual gluten quality	1987	6	3–9	1.8
	1989	5	2–9	1.7
	1990	7	5–10	1.1
Organoleptic judgment values				
80°C	1987	67	58–80	6.0
90°C	1989	72	57–82	5.7
90°C	1990	82	67–93	6.2

TABLE II
Frequency Distributions (%) of Samples for Protein Content[a]

Protein Content	1987	1989	1990
10.50–11.49	12	2	. . .
11.50–12.49	24	7	. . .
12.50–13.49	*38*	30	14
13.50–14.49	10	*40*	28
14.50–15.49	6	14	*39*
15.50–16.49	8	7	13
16.50–18.49	2	. . .	6

[a]The highest value for each year is italicized.

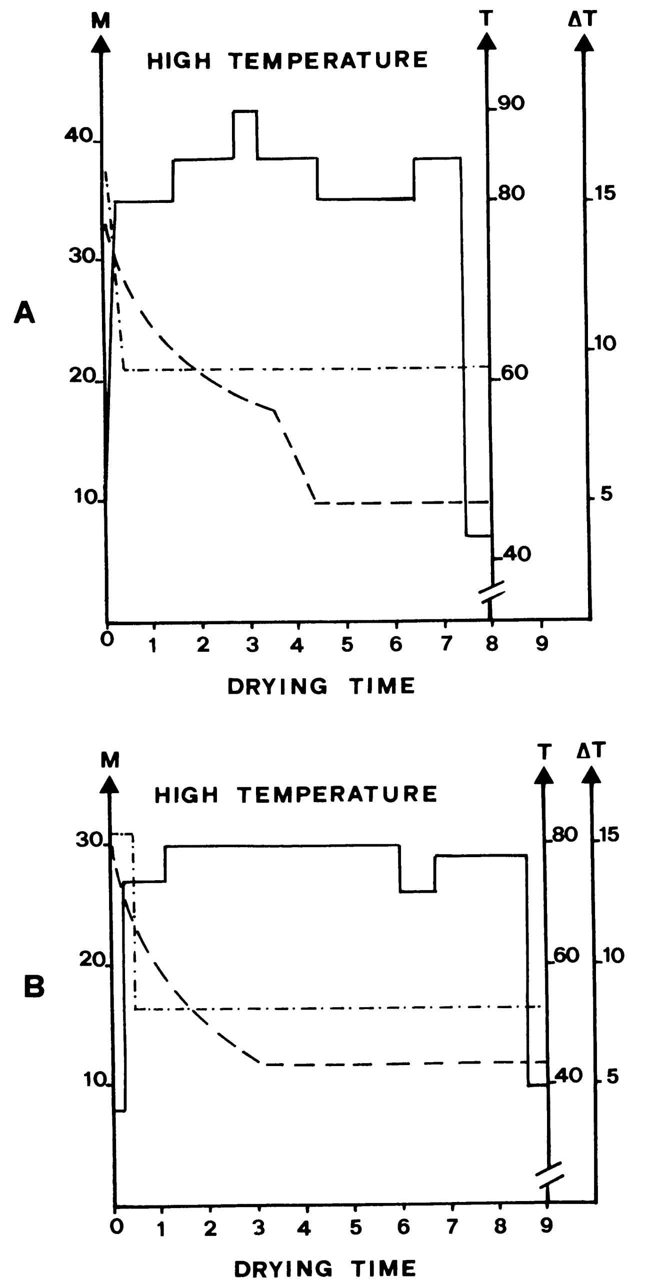

Fig. 1. Processing diagrams for high-temperature drying. M = pasta moisture (%) (– – –); T = air temperature inside dryer (°C) (——); ΔT = difference between temperatures inside dryer on dry-bulb and wet-bulb thermometers (°C) (– · · · –). **A,** 90°C; **B,** 80°C.

After this equation was applied to the 1989 and 1990 samples, the OJ percentages observed lying above, within, and below the confidence limits of the regression line were compared to those obtained for 1987 reference set (Table III). The high percentages of data lying above the confidence limits (60 and 90%, respectively, for 1989 and 1990) revealed the predictive equation underestimated OJ. Therefore, the proposed equation could not be completely accepted, and more investigation appeared to be necessary.

To examine whether the linear regressions of the 1989 and 1990 samples would be the same as that identified by the predictive equation for the 1987 reference set, we tested the residual variances, slopes, and elevations. A look at the *F* values (Table IV) shows no real difference in either residual variances or slopes; only the elevations appeared to differ significantly, and the difference of 1990 elevation versus that of 1987 was conspicuous. Hence, the regression lines of the 1989 and 1990 samples were parallel to the regression line of the 1987 reference set. Although they both shifted to more positive OJ values, the shifting of 1990 regression line was particularly high.

Because the *F* values for the two elevation comparisons were significant but very different in amount ($F = 9.42$ and 81.72, $P < 0.01$), we tried a second approach to study the distribution of the 1989 and 1990 data about the 1987 regression line. The distance of the 1989 data from the 1987 regression line was not significant ($F = 1.48$), but the regression line of 1987 could still be considered valid for the 1989 sample. In contrast, the distance for the 1990 data was highly significant ($F = 5.89$, $P < 0.01$)); therefore, the 1990 data could not be interpreted by the 1987 regression line. Both statistical approaches underlined the different behavior of 1990 sample set.

The 1990 sample was submitted to the same drying diagram (Fig. 1A) used for the 1989 sample, but it had a higher protein content. We hypothesized an interaction between a higher protein content and a higher temperature. To reveal this interaction, we applied the multiphase regression models because they evidence different trends in the same phenomenon and identify the changeover point. Among these multiphase models, a regression model with two straight lines was chosen on the assumption of linearity of the relationship between protein content and OJ at high temperature. For a more profitable application of the two-line model, the samples of 1989 and 1990 were combined, which provided a wider protein-content variability. This was possible because the two samples were linked by the same drying diagram (Fig. 1A).

Among the numerous combinations of pairs of straight lines, the best-fitting pair for the data was found, and the abscissa value, for which the lines changed their slope, was evidenced. It was possible, therefore, to find the protein level (14%) from which to determine a different relationship between OJ values and protein content.

Table V presents the regression parameters calculated for the set of combined 1989 and 1990 samples, applying the linear and two-line models. Regression coefficients for the 1987 predictive equation are reported only as a reference. To evaluate whether it would be advantageous to apply the two-line model instead of the linear model, we considered the gain in efficiency (measured by the *F* test) of reducing residual variance by using the two-line model and linear regression (Snedecor and Cochran 1980, Mariani et al 1983). The high significance of the *F* value ($F = 8.07$, $P < 0.01$) showed that the two-line model fit the data better than the linear regression did; thus, linear regression of combined 1989 and 1990 samples was rejected in favor of the two-line model. There was also a conspicuous difference between the linear regression parameters and those of 1987 predictive equation.

Upon accepting the two-line model, its parameters were compared (Table V) with those of the 1987 predictive equation. The first regression line had the same *b* value. The elevation increased about +5 (45.25 vs. 40.48). The second regression line was completely different, however; the slope was reduced to half, and elevation increased about +30.

Figure 2 compares the regression lines of two-line model used to predict OJ at 90°C with the regression line valid for samples dried at 80°C (D'Egidio et al 1990). The predictive equation established at 80°C was unique for every value of protein content.

TABLE III
Organoleptic Judgment (OJ) Observed Values (%) Lying Above, Within, and Below the 95% Confidence Limits of Regression Line Determined by Predictive Equation Proposed for 80°C

OJ Values	80°C 1987		90°C 1989		90°C 1990	
Above	34	72	60	90	90	100
Within	38		30		10	
Below	28		9		...	

TABLE IV
Comparison Between Linear Regressions: *F* Values

F Values	1989 vs. 1987 Regression	Distance of Data from 1987 Regression	1990 vs. 1987 Regression	Distance of Data from 1987 Regression
s^2_d [a]	1.02 ns[b]	1.48 ns	1.13 ns	5.89 **[c]
Slopes	0.23 ns		0.90 ns	
Elevations	9.42 **		81.72 **	

[a] Deviation from regression mean square.
[b] ns = Not significant.
[c] ** = $P = 0.01$.

TABLE V
Parameters of Linear and Two-Line Regression Models: Efficiency of Two-Line Model vs. Linear Regression of 1989 + 1990 Sample

	80°C	90°C		
	Linear Regression 1987	Linear Regression 1989 + 1990	Two-Line Model <14% Protein	Two-Line Model ≥14% Protein
Number of samples	50	112	51	61
Organoleptic judgment values	67.5	78.2	73.7	82.7
a	40.48	20.41	45.25	68.04
b	2.04	4.03	2.06	0.97
s^2_d	26.76	38.23	37.65	29.55

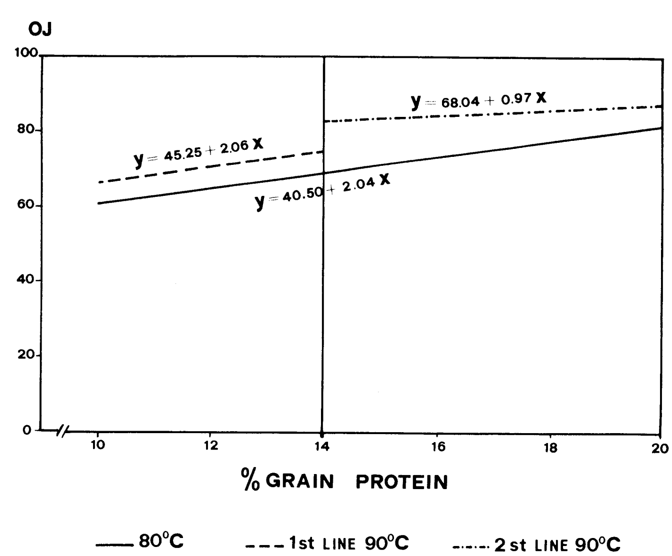

Fig. 2. Regression lines of organoleptic judgment (OJ) values at high-temperature drying on grain protein content for the two-line model (90°C) compared to that of the predictive equation determined on the 1987 reference set (80°C).

TABLE VI
Organoleptic Judgment Regressed Values and Their 95% Confidence Limits for Given Protein Contents

Protein (%, dm)	80°C	90°C First Line	90°C Second Line
11	63 ± 3	68 ± 7	
12	65 ± 2	70 ± 4	
13	67 ± 2	72 ± 2	
14	69 ± 2		82 ± 2.5
15	71 ± 2		83 ± 1.4
16	73 ± 3		84 ± 2.0
17	76 ± 4		85 ± 4.0
18	78 ± 5		86 ± 5.0

For 90°C drying system, however, the two-line model identifying the change-over point at the 14% abscissa value defined two different equations for predicting pasta quality. The first line (Table V, Fig. 2) was parallel to the 80°C line and shifted +5 to higher OJ values. Therefore, high-temperature drying applied to samples with protein content less than 14% had an additive effect on OJ (represented by a constant +5 in elevation). For samples with protein content equal to or greater than 14%, the 90°C drying system interacted with protein content in a multiplicative effect: the slope changed, the elevation increased considerably, and a completely different predictive equation was obtained. This second line (very high elevation, $a = 68.04$) already had good OJ values at the 14% protein level, but $b = 0.97$ and the OJ response was reduced. Conspicuous increases in protein content yielded small improvements in OJ (Table VI). In fact, for protein content of 14–18%, the OJ only increased from 82 to 86 for very high-quality pasta.

Upon application of the two-line model equations, the percentages of observed OJ values lying above, within, and below the confidence limits of the relative regression lines (Table VII) clearly showed a situation similar to that considered suitable and valid for the 1987 reference set (Table III). The efficiency of the two-line model equations in predicting pasta quality with high-temperature drying systems was confirmed. Notwithstanding, the 80°C predictive equation could be still used for samples with protein content less than 14% dried at 90°C by underestimating 5 scores for OJ values.

Finally, the improving effect of high-temperature drying technologies on pasta cooking quality, and the importance of protein content in those conditions, were confirmed. Moreover, it was possible to identify the level of protein content of greatest advantage for pasta quality and the limits beyond which any further improvement gave a minimum gain at high temperatures.

CONCLUSIONS

This investigation identified two equations for predicting pasta quality at 90°C:

when protein content <14%: OJ = 45.25 + 2.06 (% protein);

when protein content ≥14%: OJ = 68.04 + 0.97 (% protein).

The predictive equation of OJ for 80°C was still valid for protein content < 14% at 90°C drying temperatures, even when OJ was slightly underestimated.

The different behavior for protein content ±14% confirmed the importance of raw material characteristics in obtaining pasta of very good quality when using high-temperature drying systems.

High-temperature drying technologies are widespread, so it is not necessary for durum wheat breeding programs to force the selection for grain protein content over 15–16% because there is very limited improvement in OJ.

TABLE VII
Organoleptic Judgment Observed Values (%) Lying Above, Within, and Below the 95% Confidence Limits of Regression Lines Determined by Two-Line Model

Values	First Line	Second Line
Above	35 } 59	34 } 67
Within	24	33
Below	41	33

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[Received March 23, 1993. Accepted August 5, 1993.]