Effects of Drying Temperature and Farina Blending on Spaghetti Quality Using Response Surface Methodology

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ABSTRACT

Response surface methodology was used to analyze the effects of peak drying temperature and blending of hard red spring farina with durum semolina on the quality characteristics of spaghetti. Five peak drying temperatures (40, 60, 70, 80, and 90° C) and five blends of farina and durum (0:100, 25:75, 50:50, 75:25, and 100:0) were studied. Good-fit models were developed for compression and relaxation time of optimally cooked spaghetti, for firmness and compression of overcooked spaghetti, and for brightness. Models developed for firmness of optimally cooked spaghetti, relaxation time of overcooked spaghetti, purity, and dominant wavelength did not meet all of the criteria of good fit but nevertheless provided useful information for an initial screening study. Models for strand stickiness and cooking loss had low predictive ability. The superimposition of the individual contour plots permitted the identification of the region where all predicted characteristics met or exceeded commercial durum spaghetti samples. The most limiting factors were the firmness of optimally cooked spaghetti, relaxation time of overcooked spaghetti, and dominant wavelength. To satisfy these constraints, durum levels greater than 60% and peak drying temperatures above 60° C were required.

Although durum wheat is considered the best raw material for pasta production, the use of nondurum wheat is permitted in Canada and the United States and largely depends on the availability and price of durum semolina. Thus, there is interest in determining the effect of farina blending on the cooking quality of spaghetti.

Sheu et al (1967) reported that pasta made from hard red spring (HRS) farina had lower cooking losses and cooked weight and was firmer than was spaghetti made from durum semolina. This was confirmed by Mousa et al (1983) using spaghetti made with durum semolina and with HRS and hard red winter (HRW) farina. Both HRS and HRW spaghetti were firmer and had lower cooked weight and cooking loss values than did spaghetti made from durum. As expected, durum spaghetti had higher color scores than did the other spaghetti.

In studies done on farina blending, Wyland and D'Appolonia (1982) found a similar trend. As the level of HRS increased in the spaghetti, firmness increased; cooking loss, cooked weight, and spaghetti color decreased. In contrast, Dexter et al (1981c) found that cooking scores decreased as farina levels increased, especially when the spaghetti was overcooked, indicating that spaghetti containing farina was not as tolerant to overcooking as was durum spaghetti. Dexter et al (1983) suggested that this discrepancy could be explained by the fact that the cooking quality of American durum was poorer than that of Canadian durum in these earlier studies.

Studies done by Kim et al (1986, 1989) on semolina and farina spaghetti were in agreement with the study by Dexter et al (1981c). Spaghetti made with semolina had a firmer texture than did spaghetti made with farina. Kim et al (1986) found that durum spaghetti had higher cooking losses than did farina spaghetti when cooked in distilled water, whereas the opposite was found when the spaghetti was cooked in prepared hard water (Kim et al 1989). They also reported that spaghetti made from durum was less sticky than was spaghetti made from farina. A recent study by Cole et al (1990) suggested that incorporation of hard wheat flour into pregelatinized pasta formulations would result in a firmer product than would the use of durum semolina. Thus, the effects of farina blending on the cooking quality of pasta are not in agreement and merit further investigation.

High temperature (HT) drying has been shown to improve spaghetti cooking quality if applied after initial drying at low temperature (LT) to low moisture levels (Dexter et al 1981b, 1984; Wyland and D'Appolonia 1982; Resmini and Pagani 1983; Abecassis et al 1989a,b). Several workers have suggested that with HT drying, the quality of the raw material may no longer be as critical (Feillet 1984, Matsuo 1988, Cubadda 1989). Thus, it may be possible to produce spaghetti with good cooking quality using blends of durum semolina and HRS farina using HT drying. Kim et al (1989) found that both semolina and farina spaghetti dried under HT (70°C) conditions were firmer, less sticky, and had lower cooking losses than did samples dried under LT (45°C) conditions. Results of Dexter et al (1983) were in agreement with those of Kim et al (1989), except that firmness of farina spaghetti was not found to improve with HT drying over that of durum spaghetti. Wyland and D'Appolonia (1982) examined the effect of farina blending with drying temperatures of 40, 60, 70, and 80°C. As drying temperature increased, firmness also increased and cooking loss values decreased. Spaghetti stickiness was not measured. The authors did not indicate what combinations of farina blends and drying temperatures gave optimum cooking quality, thereby limiting the conclusions that can be drawn from this study.

Thus, the use of HT drying conditions appears promising in terms of improving the cooking quality of spaghetti prepared from blends of semolina and farina. More work needs to be done, however, to examine the relationship of spaghetti drying temperature and farina blending on the cooking quality of spaghetti, with the goal of determining which combinations of drying temperatures and farina blends yield an optimal spaghetti. Because such a study could be excessive in terms of the possible treatment combinations that could be examined, the use of response surface methodology (RSM) appears beneficial. RSM is a statistical technique used to determine optimal conditions in a minimal number of experimental trials. It has been used successfully in a number of product optimization studies on whipped topping (Min and Thomas 1980), bread (Henselman et al 1974), cake (Vaisey-Genser et al 1987), and noodles (Oh et al 1985, Shelke et al 1990). To date, no studies have been undertaken to optimize peak drying temperatures for processing of spaghetti or to optimize the replacement of durum semolina with HRS farina. Thus, the objective of this study was to examine the relationship between spaghetti peak drying temperature and blending of HRS farina with durum semolina on the cooking quality of optimally cooked and overcooked spaghetti using RSM.

MATERIALS AND METHODS

Preparation and Analysis of Blends

A 10-kg sample of durum semolina and HRS wheat middlings (farina) were obtained from Ogilvie Mills Ltd, Montreal. Three blends of semolina and farina (75:25, 50:50, and 25:75) were

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prepared on a dry-matter basis. The three blends, plus a sample of 100% semolina and 100% farina, for a total of five treatment blends, were then analyzed for protein content by the standard Kjeldahl method as modified by Williams (1973). Four-gram samples were placed in silica dishes and incinerated overnight (approximately 16 hr) at 600°C to determine ash content. After being cooled, the dishes and ash were weight, the ash was brushed out, dishes were reweighed, and the weight of the ash was determined by the difference. Determinations of protein and ash were performed in duplicate.

Wet gluten content of the five blends was determined in duplicate using the Glutomatic system according to ICC standard method no. 137 (1982).

Spaghetti Processing and Drying

Spaghetti was processed in a Demaco S-25 laboratory scale continuous extrusion press (De Francisci Machine Corporation, Brooklyn, NY) as described by Matsuo et al (1978). Samples were dried using five peak drying temperature conditions (40, 60, 70, 80, and 90°C) modeled after commercial drying cycles. A modified Blue M FR-381C environment chamber (Blue M Electric Co., Blue Island, IL) as described by Dexter et al (1981a) was used for drying the spaghetti. In the 40°C drying cycle, spaghetti was dried over a 16-hr period with a controlled decrease in relative humidity. Temperature was maintained at 40°C for the entire 16-hr period, followed by equilibration to room temperature conditions. The 60 and 70° C cycles featured an initial 10-hr exposure to the high temperature followed by a decrease in temperature to 40°C. That temperature was held for 6 hr before equilibration to room conditions. The 80 and 90°C cycles featured a short initial exposure to high temperature followed by a decrease to 70°C where it was held for several hours. This was followed by a decrease in temperature to 40°C and finally equilibration.

Experimental Design

RSM was chosen as the means by which the effects of blending levels and peak drying temperatures could be approximated over the experimental region. The second-order response surface was fitted to the data as an approximation to the true response surface. We felt this approximation was appropriate even though we had some reservation about the use of peak drying temperature as an interval scale factor. However, because the focus of this study was to find regions of improved response over the experimental conditions rather than to find the exact optimum response, we considered the use of RSM to be appropriate given the exploratory nature of the method.

Figure 1 presents the experimental design selected, which consisted of nine design points and included four replications of the center point and two replications of the interior points for a total of 16 samples. These samples were processed in random order over a three-week period, and spaghetti was tested in random order over a four-day period.

Assessment of Cooked Spaghetti Quality

Spaghetti samples were cooked to optimum (defined as the time when the center core disappears) and to optimum plus 10 min (overcooked) in prepared hard water (Malcolmson 1991).

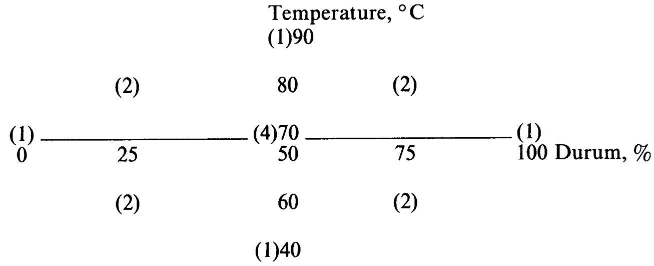

Fig. 1. Nine design points of the two-variable composite design. Number in parentheses is number of samples prepared for evaluation at the design point selected.

Cooking loss of the recovered water was determined by freeze-drying, weighing the freeze-dried material, adjusting for mineral residue present in the cooking water, and calculating the proportion of solids lost to the cooking water as the percentage of spaghetti cooked.

Instron firmness, compression, relaxation, and strand stickiness were then determined as described by Malcolmson (1991).

Color Assessment of Spaghetti

Spaghetti color was assessed on whole strands of uncooked spaghetti mounted on white cardboard by reflectance using a Beckman DU-7 spectrophotometer (Beckman Instruments Inc., Fullerton, CA). Dominant wavelength, brightness, and purity were determined by the 10 selected ordinates method (Hardy 1936).

Statistical Analysis of Data

Data were analyzed using the RSREG procedure of the SAS Institute (1988) to fit second-order polynomial equations for all response variables. Lack-of-fit tests were performed on the fitted models. Coefficients for the linear, quadratic, and interaction terms of each model were calculated and tested for difference from zero. Two-dimensional contour plots were generated from the fitted models using the GCONTOUR procedure (SAS Institute 1988). These plots were superimposed to determine the region where levels of durum semolina and drying temperatures produced spaghetti predicted to be comparable in quality to commercial durum spaghetti. Acceptable commercial quality was assessed on seven brands of durum spaghetti available in the marketplace.

RESULTS AND DISCUSSION

Semolina and Farina Characteristics

Protein, ash, and gluten content of the five prepared blends of durum semolina and HRS farina are provided in Table I. Protein levels were similar for the five blends with a range of 12.0–12.4%. As expected, ash content increased with the level of durum semolina in the blend. Wet gluten content increased slightly with increasing levels of durum semolina in the blend.

Response Surface Analysis

The analyses of variance for cooking quality of optimally cooked and overcooked spaghetti are presented in Tables II and III, respectively. Significance of the lack-of-fit error term, R^2 value, coefficient of variation (CV), and model significance were used to judge adequacy of model fit. The predictive models developed for compression and relaxation time of optimally cooked spaghetti and firmness and compression of overcooked spaghetti were considered adequate because they possessed no significant lack of fit and had satisfactory levels of R^2, CV, and model significance. The developed model for firmness of optimally cooked spaghetti was less predictive because the R^2 was less than 0.60 (0.51) and the model was not significant at the 5% level (P = 0.15). The model developed for relaxation time of overcooked spaghetti had adequate R^2, CV, and model significance but showed a significant lack of fit, suggesting that the second-order model was not adequate. Models developed for strand stickiness and cooking loss of optimally cooked spaghetti and overcooked spaghetti were judged to be inadequate because of very low levels of R^2, high CV, and lack of model significance.

The analyses of variance for spaghetti color parameters are

TABLE I
Protein, Ash, and Wet Gluten Content[a] of Prepared Blends of Durum Semolina and Hard Red Spring Farina

	Blend (% durum semolina)				
Quality	**0**	**25**	**50**	**75**	**100**
Protein, %	12.0	12.2	12.1	12.4	12.4
Ash, %	0.37	0.44	0.53	0.59	0.65
Wet Gluten, %	31.5	32.0	32.4	32.9	32.8

[a] 14.0% moisture basis.

TABLE II
Analysis of Variance for Evaluation of Models for Quality Parameters of Optimally Cooked Spaghetti

Response		Source	df	Sum of Squares	*F* Value	*P* Value
Firmness (shear force)		Model	5	0.745	2.062	0.154
		Residual	10	0.723		
		Lack of fit	3	0.276	1.439	0.311
		Pure error	7	0.002		
R^2	0.51					
CV, %	5.2					
Compression energy		Model	5	0.299	6.192	0.007
		Residual	10	0.097		
		Lack of fit	3	0.003	0.789	0.969
		Pure error	7	0.093		
R^2	0.76					
CV, %	3.9					
Relaxation time		Model	5	423.376	15.270	0.001
		Residual	10	55.452		
		Lack of fit	3	21.385	1.465	0.304
		Pure error	7	34.067		
R^2	0.88					
CV, %	8.9					
Strand stickiness		Model	5	141,898.0	1.567	0.255
		Residual	10	181,145.0		
		Lack of fit	3	122,545.0	4.880	0.039
		Pure error	7	58,600.0		
R^2	0.44					
CV, %	13.1					
Cooking loss		Model	5	2.915	0.586	0.711
		Residual	10	9.942		
		Lack of fit	3	4.782	2.162	0.181
		Pure error	7	5.160		
R^2	0.23					
CV, %	20.19					

TABLE III
Analysis of Variance for Evaluation of Models for Quality Parameters of Overcooked Spaghetti

Response		Source	df	Sum of Squares	*F* Value	*P* Value
Firmness (shear force)		Model	5	0.886	7.866	0.003
		Residual	10	0.225		
		Lack of fit	3	0.036	0.446	0.728
		Pure error	7	0.189		
R^2	0.79					
CV, %	3.9					
Compression energy		Model	5	0.147	3.303	0.051
		Residual	10	0.089		
		Lack of fit	3	0.034	1.494	0.297
		Pure error	7	0.054		
R^2	0.65					
CV, %	23.2					
Relaxation time		Model	5	50.997	4.669	0.019
		Residual	10	21.846		
		Lack of fit	3	15.694	5.952	0.024
		Pure error	7	6.152		
R^2	0.70					
CV, %	9.9					
Strand stickiness		Model	5	182,236.0	0.533	0.747
		Residual	10	683,564.0		
		Lack of fit	3	91,414.0	0.360	0.783
		Pure error	7	592,150.0		
R^2	0.21					
CV, %	19.0					
Cooking loss		Model	5	5.434	1.588	0.249
		Residual	10	6.843		
		Lack of fit	3	2.691	1.512	0.293
		Pure error	7	4.415		
R^2	0.44					
CV, %	11.51					

TABLE IV
Analysis of Variance for Evaluation of Models for Spaghetti Color

Response		Source	df	Sum of Squares	*F* Value	*P* Value
Brightness		Model	5	37.820	21.655	0.000
		Residual	10	3.492		
		Lack of fit	3	2.277	4.371	0.049
		Pure error	7	1.216		
R^2	0.92					
CV, %	1.2					
Purity		Model	5	198.673	57.525	0.000
		Residual	10	6.907		
		Lack of fit	3	1.704	0.764	0.549
		Pure error	7	5.203		
R^2	0.97					
CV, %	2.0					
Dominant wavelength		Model	5	1.338	11.502	0.001
		Residual	10	0.233		
		Lack of fit	3	0.197	12.661	0.003
		Pure error	7	0.036		
R^2	0.85					
CV, %	0.1					

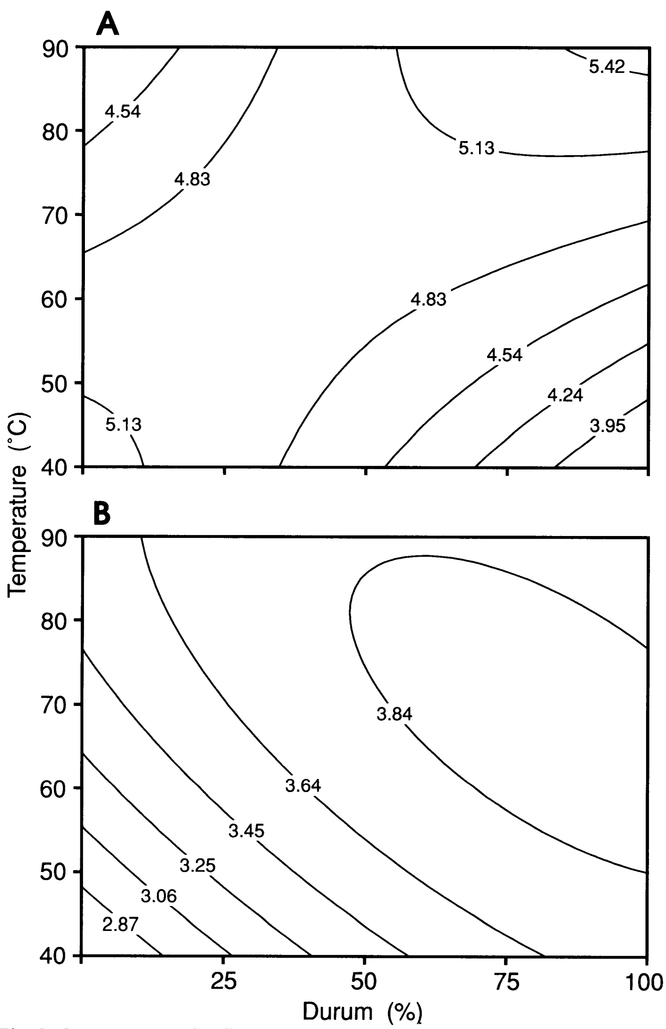

Fig. 2. Contour plots for firmness of optimally cooked (**A**) and overcooked (**B**) spaghetti.

presented in Table IV. The predictive model developed for purity was considered adequate because it possessed no significant lack of fit and had satisfactory levels of R^2, CV, and model significance. The models developed for brightness and dominant wavelength also had adequate levels of R^2, CV, and model significance but had significant lack of fit, suggesting that the second order models were not adequate.

To visualize the combined effects of the two independent variables of durum semolina level and peak drying temperature on the dependent responses of cooked quality and color, two-dimensional contour plots were generated for each of the fitted models. The contour plots show predicted cooking quality and color characteristics for all combinations of durum semolina level and peak drying temperature.

The contour plot for firmness of optimally cooked spaghetti is presented in Figure 2A. The region of optimum firmness is in the upper right corner, with high levels of durum semolina and high peak drying temperatures. The area of minimum response was defined by high levels of durum and low peak drying temperatures. The region of optimum firmness for overcooked spaghetti was defined by semolina levels greater than 50% and peak drying temperatures above 50° C (Fig. 2B). In contrast to optimally cooked spaghetti, the region of minimum response was located in the direction of low durum levels and low peak drying temperatures.

Contour plots for compression are presented in Figure 3. Lower compression values (indicating superior cooking quality) were achieved for optimally and overcooked spaghetti in the direction of high levels of durum semolina and high peak drying temperature. A region of maximum response for optimally cooked spaghetti was found with low durum levels and low peak drying temperatures. For overcooked spaghetti, two regions of maximum response were found—one defined by low durum levels and high peak drying temperatures and the other defined by high durum levels and low peak drying temperatures.

Relaxation time of optimally cooked spaghetti was affected more by changes in peak drying temperature than by changes in durum level (Fig. 4A). The area of optimized response was located in the upper corner with high peak drying temperatures and high durum levels. The region of minimal response was found in the direction of low peak drying temperatures and low durum levels. The region of optimization for relaxation of overcooked spaghetti was at the highest durum level (100%) and peak drying temperatures above 60° C (Fig. 4B). Minimum responses were achieved at 40° C and durum levels around 30%.

Contour plots for color parameters are presented in Figures 5–7. Purity is an indication of hue or color intensity and is therefore related to pigment content. A high value for purity is desirable. Brightness is a measure of the amount of light reflected from the surface of the spaghetti relative to that reflected from a white surface. Brightness values tend to decrease with increasing values of purity. Dominant wavelength is an indicator of "off color." Values between 576 and 577 nm indicate a desirable amber yellow color, values lower than 576 indicate a less desirable yellow color that is slightly greenish, and values greater than 577 indicate a brownish tinge.

Brightness values decreased with increasing durum levels and peak drying temperatures (Fig. 5). The area of minimal response was defined by high peak drying temperature and high durum levels, whereas the area of maximum response was defined by low peak drying temperatures and low durum levels.

Contour plots for purity and dominant wavelength were generated even though a significant lack of fit was found for both models, suggesting the possibility of missing components. We felt that the models developed offered a reasonable and meaningful starting point in the effort to model color responses in spaghetti. Purity was affected more by durum levels than by peak drying temperature (Fig. 6). The area of maximum response was defined by the highest durum levels over the predicted full range of peak drying temperatures. Minimum responses were found with low durum levels and low peak drying temperatures, although durum levels appeared to be the more important of the two variables. Dominant wavelength showed a greater change in the surface contour along the drying temperature axis than along the durum semolina level axis (Fig. 7). With higher peak drying temperatures and, to a lesser extent, higher durum levels, dominant wavelength values begin to move out of the ideal range above 577 nm. Optimum responses were defined by peak drying temperatures below 80°C across the full range of durum levels.

In summary, the predicted optimum responses for firmness, compression, and elasticity of optimally cooked spaghetti were produced with a combination of high durum levels and high peak drying temperatures. These results are not unexpected, because durum semolina spaghetti has been reported to be firmer, more elastic, and less sticky than is spaghetti made with HRS wheat farina (Dexter et al 1981c, 1983b; Manser 1980; Kim et al 1986, 1989). Also, spaghetti dried under HT conditions has been found to have better cooking quality than does spaghetti dried under LT conditions (Manser 1980; Wyland and D'Appolonia 1982; Dexter et al 1981b, 1984; Abecassis et al 1984).

Predicted optimum responses for firmness, compression, and elasticity of overcooked spaghetti were found over a wide range of peak drying temperatures. Optimum relaxation time of overcooked spaghetti was achieved at 100% durum levels, optimum

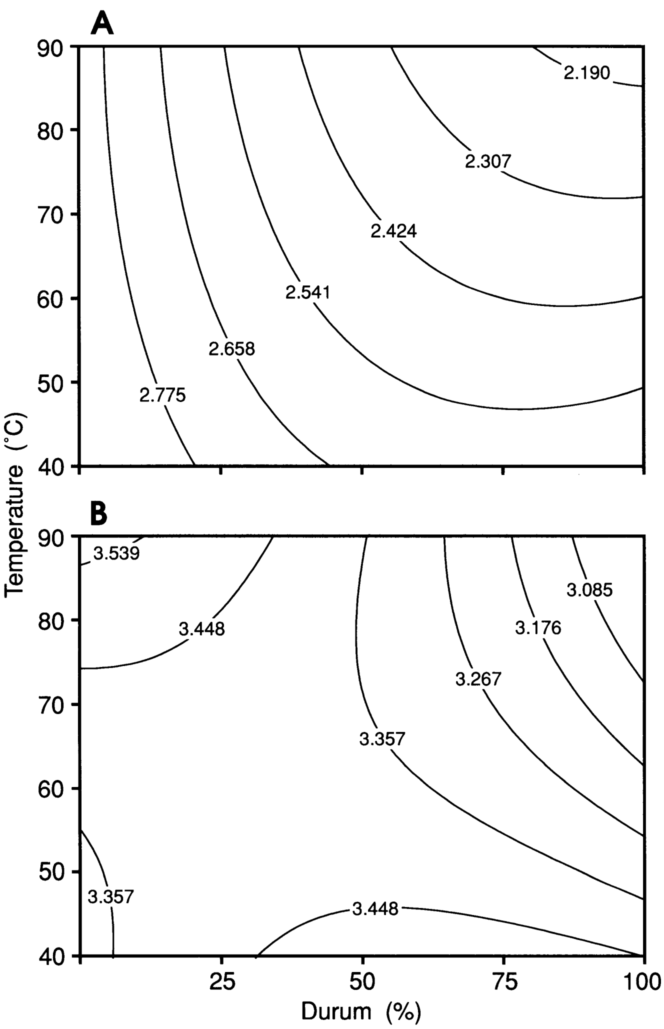

Fig. 3. Contour plots for compression energy of optimally cooked **(A)** and overcooked **(B)** spaghetti.

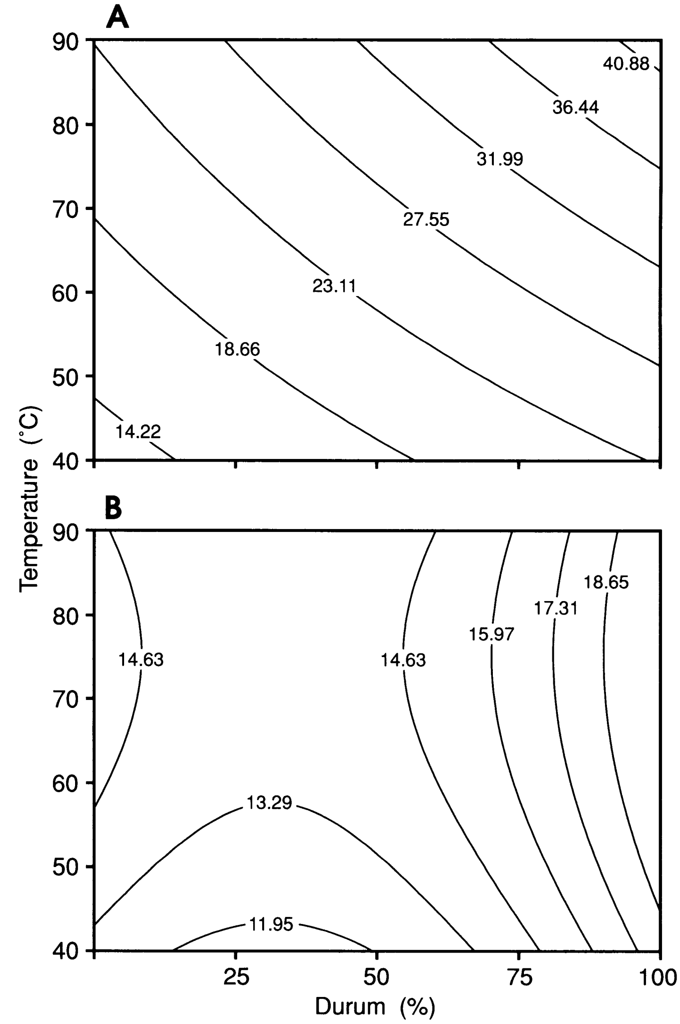

Fig. 4. Contour plots for relaxation time for optimally cooked **(A)** and overcooked **(B)** spaghetti.

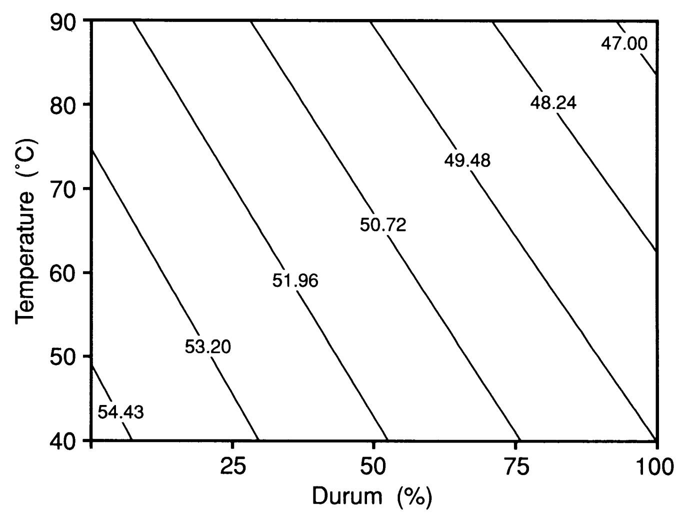

Fig. 5. Contour plot for brightness.

compression energy was found at durum levels between 25 and 50%, and optimum firmness was achieved at durum levels greater than 50%.

Predicted optimum responses for purity were achieved at high durum levels (a reflection of increasing yellow pigment content) over the full range of peak drying temperatures. Brightness tended to diminish with combinations of high durum levels and high peak drying temperatures. Optimum responses for dominant wavelength were found at peak drying temperatures below 80°C over the full range of durum levels. Color scores have been found to decrease with HRS farina spaghetti (Dexter et al 1981c; Wyland and D'Appolonia 1982; Mousa et al 1983; Kim et al 1986, 1989).

HT drying has been shown to decrease brightness and increase purity and dominant wavelength (Dexter et al 1984). Kim et al (1989) also found pigment retention was greater in both farina and semolina spaghetti dried under HT conditions than that dried under LT conditions. The tendency of HT spaghetti to develop a slight undesirable brownness has been attributed to Maillard reactions (Laignelet 1977, Manser 1978, Pavan 1979), although some of the effect could be due to increased oxidase activities during drying (Kobrehel et al 1974, Feillet et al 1974). The Maillard reaction in spaghetti has been linked to relative humidity as well as to drying temperature (Laignelet 1977), which suggests that controlling the relative humidity during drying may limit the reaction. As well, Pavan (1979) stated that drying temperatures below 80°C did not pose any problem for browning to occur. Results of this study are in agreement with observations made by Pavan.

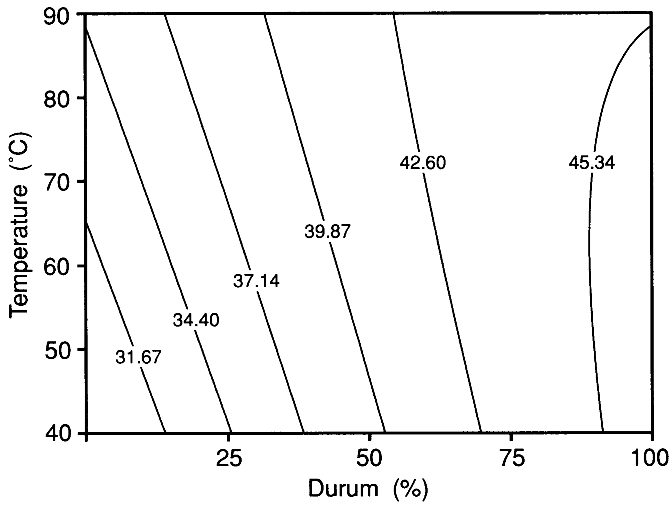

Fig. 6. Contour plot for purity.

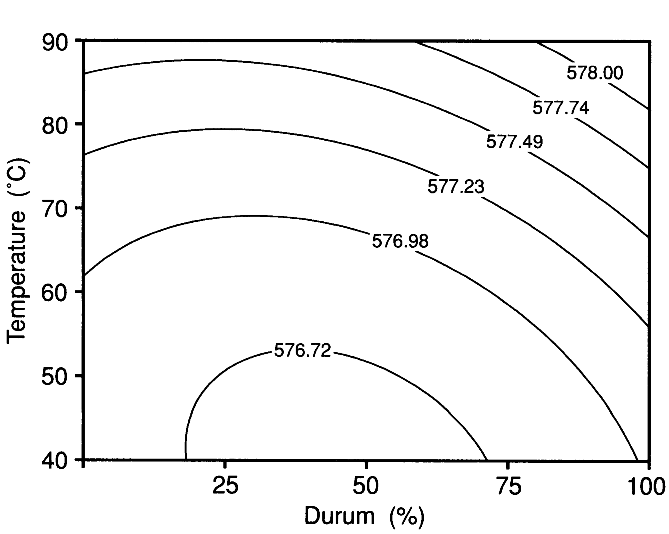

Fig. 7. Contour plot for dominant wavelength.

Cooking quality values and color values for commercial durum spaghetti samples are presented in Table V. Experimental spaghetti generally met or exceeded these values. Two-dimensional contour plots for all responses were superimposed to locate spaghetti formulation and drying conditions that met commercial durum spaghetti standards for all responses. The use of a multiple contour plot to establish a region of acceptability has been employed by several researchers (Oh et al 1985, Vaisey-Genser et al 1987, Shelke et al 1990). As indicated in Figure 8, limiting parameters were firmness of optimally cooked spaghetti, relaxation time of overcooked spaghetti, and dominant wavelength. Thus, the shaded area in the upper right quadrant of the plot represents the region where all cooking quality characteristics of optimally cooked and overcooked spaghetti and all color characteristics are equal to or exceed commercial durum spaghetti limits for these parameters. Levels of durum semolina must exceed 60% and peak drying temperatures must be above 60°C to achieve spaghetti with satisfactory quality.

CONCLUSIONS

In this study, RSM was successfully used to identify the effects of peak drying temperature and blending of HRS farina with durum semolina on the cooking quality and color characteristics of spaghetti. Good-fit models were developed for compression and relaxation time of optimally cooked spaghetti, firmness and compression of overcooked spaghetti, and brightness. Models developed for firmness of optimally cooked spaghetti, relaxation time of overcooked spaghetti, purity, and dominant wavelength did not meet all of the criteria of good fit. Contour plots were generated for these models, however, because they offered a

TABLE V
Cooking Quality and Color Measurements of Commercial Durum Spaghetti

Cooking Quality Parameter	Color Parameter	Commercial Range: Optimally Cooked	Commercial Range: Overcooked
Firmness, N		4.7–5.7	3.3–4.6
Compression energy, $N \cdot$mm		2.0–2.4	2.7–3.4
Relaxation time, sec		25–45	15–24
Strand stickiness, mm^2		483–805	585–850
Cooking loss, %		5.5–6.4	7.3–9.6
	Purity	36.9–43.7	
	Brightness	45.7–51.4	
	Dominant wavelength	577.2–578.3	

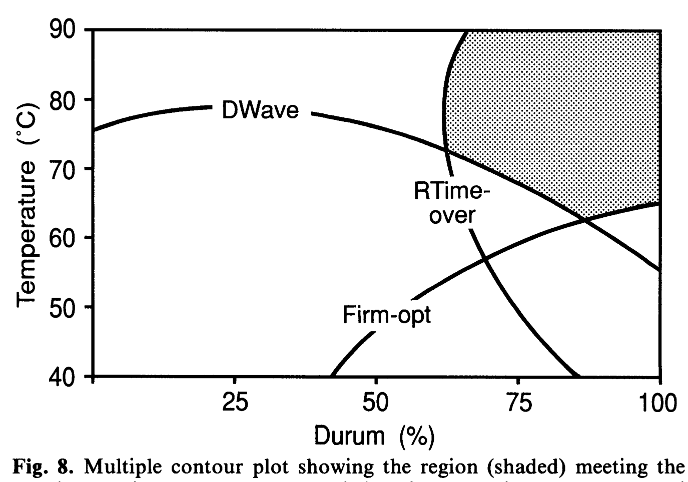

Fig. 8. Multiple contour plot showing the region (shaded) meeting the cooking quality and color characteristics of commercial durum spaghetti samples. Firm-opt = firmness of optimally cooked spaghetti, RTime-over = relaxation time of overcooked spaghetti, and DWave = dominant wavelength.

reasonable initial solution for describing the quality responses of these parameters in spaghetti. Models for strand stickiness and cooking loss had low predictive ability. Contour plots, generated from fitted models for firmness, compression, and relaxation of optimally cooked spaghetti, indicated that high durum levels in combination with high peak drying temperature was the region of optimized response. Peak drying temperatures were not as critical for firmness, relaxation, and compression of overcooked spaghetti, although high levels of durum semolina were important in optimizing these responses. The color parameter of brightness was found to diminish, whereas purity was found to intensify with high durum levels and high peak drying temperatures. The area of optimized response for dominant wavelength was defined by peak drying temperatures below 80°C.

Superimposing the individual contour plots for all response variables exhibiting reasonable model fit permitted the identification of the region where all characteristics met or exceeded commercial durum spaghetti samples. The most limiting factors were firmness of optimally cooked spaghetti, relaxation time of overcooked spaghetti, and dominant wavelength. Thus, to satisfy these constraints, durum levels greater than 60% are required with peak drying temperatures above 60°C. Within this optimized region, a number of combinations of durum semolina levels and peak drying temperatures can be identified that will yield acceptable spaghetti. For instance, it is predicted that at the minimum durum semolina level (60%), peak drying temperatures between 70 and 90°C will impart acceptable cooking quality characteristics to the spaghetti, whereas at 100% durum semolina level, peak drying temperatures between 60 and 90°C are predicted. Thus, as the level of durum semolina increases in the blend, lower peak drying temperatures can be used. However, if a higher quality spaghetti is desired, high levels of durum semolina coupled with high peak drying temperatures, are indicated.

The predictive models developed in this study not only provide an understanding of the interaction between spaghetti formulation and peak drying temperature but should serve as a guide for selecting final product processing and ingredient conditions. The models for all response variables proposed in this study will, however, require additional study to verify and further extend their applicability. This is particularly true for the models for strand stickiness and cooking loss. In addition, other response variables should also be examined now that the initial screening experiment has narrowed the region of durum levels and peak drying temperatures that should be studied in more detail.

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