Chinese Wet Noodle Formulation: A Response Surface Methodology Study[1]

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ABSTRACT

After a preliminary testing of 10 commercial Southeast Asian noodle flours, brands A and B were used to determine optimum formulation for Chinese wet noodles. The response surface study consisted of 27 combinations of the following independent variables: flour protein level (10.5–12.7%), sodium chloride (0.0–3.34%), and sodium carbonate (0.0–2.0%). Noodle quality attributes measured for each formulation combination were color, pH, firmness, mold growth, and odor. Sodium carbonate affected all properties of partially cooked noodles; protein level affected firmness, and sodium chloride had little influence on the noodle quality parameters examined. Among the interaction terms, the only significant ($P < 0.01$) contribution to any noodle quality parameter was that of sodium carbonate and protein content on color. The results suggest that a Chinese wet noodle of excellent quality can be made from a wheat flour in the 10.0–11.5% protein range, using 1.4–1.7% sodium chloride and 0.7–1.2% sodium carbonate.

Chinese wet noodles, also known as "boiled noodles" or "Hokkien mee" are possibly the most popular kind of noodles in Southeast Asia (Moss 1971). Essentially, this kind of noodle is obtained by partially cooking raw noodles for a short period of time (1–2 min) resulting in a fine core of dough in the center, surrounded by cooked or gelatinized dough. The noodles are made available to the consumer in this partially cooked form and are then reboiled prior to consumption.

Noodle quality has two distinct aspects: appearance and eating quality. Color and brightness are a part of the appearance aspect. Color preference varies with the region, although most consumers prefer a clear pale yellow product free from specks and discoloration. A certain degree of translucency and glossiness adds to product appeal. Chinese wet noodles are unique with regard to their eating quality requirements: a firm "al dente" product is considered desirable.

Currently there is a need for scientific information to show how wheat flour and other components can best be utilized in the production of Oriental types of noodles. Chinese wet noodles were selected for this study because of their simple formulation and relative popularity.

The purpose of this study was to find an optimum formulation for Chinese wet noodles. This involved a detailed analysis of selected Southeast Asian noodle flours and the effect of selected ingredients on noodle quality. A response surface study was done using a fractional factorial design consisting of three variables at three levels.

MATERIALS AND METHODS

Flour

Samples of flour typically used for wet noodle manufacture in Southeast Asia were received from Thailand, Malaysia, Indonesia, and Singapore. No speculation is made regarding the origin of the wheats or their class. The samples were tested (data not shown) for proximate composition and rheological performance.

Two of these flours, labeled A (10.5% protein and 0.52% ash, 14.0% mb) and B (12.7% protein and 0.56% ash, 14.0% mb), were selected for use in this investigation because they possessed different levels of protein and ash content. With a maltose content of 19 mg/10 g of flour, brand A was brighter and had a higher amylograph peak viscosity (3,310 BU) than brand B (2,980 BU) and was free from sprout damage (falling number 375). Brand B was known to have fungal amylase supplementation (falling number 250) and a maltose content of 23 mg/10 g flour. Starch damage contents were low for both brands and the flours showed no oxidizing agents present as indicated by the extensigraph. Flour brand A was known to be a raw material in demand for making Chinese wet noodles in Southeast Asia.

Equal parts of flour brands A and B were blended together to give a third flour with an intermediate protein level for the response surface study designed to determine optimum Chinese wet noodle formulation. Flours A and B were obtained from a commercial flour mill in Malaysia.

Chemicals

Food grade sodium chloride and sodium carbonate (Fisher Scientific Co., Minneapolis, MN) were used.

Experimental Design

A response surface design described by Cochran and Cox (1971) was used to study the relative contribution of a variable to noodle quality and to determine the optimum noodle formulation. Following preliminary trials, three independent variables were selected: flour protein level (10.5, 11.6, and 12.7, 14.0% moisture basis), sodium chloride (0, 1.67, and 3.34%) and sodium carbonate (0, 1.0, and 2.0%) concentrations, the latter two expressed on flour weight basis. The experimental design, which consisted of three variables at three levels, required 27 formula combinations. The combinations included a formulation having intermediate levels of the three variables replicated 10 times and tested for the purpose of measuring inherent variance in the technique. The design was randomized to increase precision. Five dependent variables were measured for each treatment. They were color, pH, firmness, mold growth, and odor.

The data obtained from this study were treated by multiple regression analysis for a second-order response surface equation which contained linear, quadratic, and interaction terms for the three independent variables. The best final equation was found using the stepwise regression procedure described by Draper and Smith (1981). To determine the effects of the variables on the quality of the noodles, contour plots for each quality parameter were generated as a function of two variables while the other variable was held constant. The optimum formulation for Chinese wet noodles was obtained by superimposing the contour plots.

Moisture

Flour moisture contents were determined in triplicate using the Brabender moisture oven according to the AACC approved air-oven method 44-15 (1983). The semiautomatic moisture tester

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(Brabender Corporation, South Hackensack, NJ) was used to heat 10 g of flour at 130°C for 1 hr.

Protein

Flour protein contents were determined in triplicate by the standard Kjeldahl method according to method 46-11A (AACC 1983). The results were reported on a 14.0% moisture basis.

Noodle Preparation

The standard formula for this study consisted of 100 parts of flour, 30–38 parts added water, 1.0 part sodium carbonate, and 1.5 parts salt (Dick et al 1986). The optimum water absorption was determined by the appearance and handling properties of the dough sheet. While insufficient water gave a sheet with jagged edges and nonuniform surface, excess water rendered the dough sheet too extensible and difficult to handle. A dough sheet with a smooth uniform surface and sharp edges was considered optimum.

The dough was mixed at high speed in a Hobart model 950 mixer (The Hobart Manufacturing Co., Ltd., Troy, OH). Water, brine, or solution in use was added over 30 sec; the mixing was interrupted at 2 min after start to scrape down the sides of bowl and beater with a spatula. The total mixing time was 5 min. At the end of the mixing stage, the mixture appeared crumbly with nodules of dough having an average diameter less than 3 mm.

The mixture was transferred to the Ohtake Noodle Machine (Ohtake Noodle Machine Manufacturing Co., Ltd., Tokyo, Japan) to press into an initial dough sheet by passage between smooth rolls set at a gap setting of 3.8 mm. The noodle machine was set at low speed (setting 1) to facilitate handling. The sheet was folded in half and passed between two rollers perpendicular to the fold at a roll gap setting of 5.68 mm. This cycle was repeated six times. The dough sheet was then gradually reduced in thickness without folding, by passing it between the rolls twice at each of the following gap settings: 3.8, 2.7, and 1.75 mm. A reduction (verified using calipers) in dough-sheet thickness ranging from 29 to 33% was obtained between each subsequent setting.

The sheet was dusted lightly on both sides with commercial cornstarch and then passed through the cutter rolls to slit into strands. The noodle so formed was approximately 2.3 mm thick and 2.5 mm wide. The noodles were weighed and placed in polyethylene bags to rest for 30 min at room temperature (25°C).

Partial Noodle Cooking

Noodles (100 g) were cooked in 1,000 ml of boiling distilled water in a Pyrex beaker according to the procedure developed by Dick et al (1986). The water was maintained at a gentle boil (98 ± 0.5°C), the noodles were dropped into the water and stirred with bamboo sticks. The noodles were cooked for a standard time (1 min, 30 sec). They were then rinsed for 1 min under cold running tap water, drained for 1 min, weighed, placed in polyethylene bags, sealed and allowed to rest for 30 min at room temperature (25°C). Each trial was done in triplicate.

Quality Evaluation of Noodles

Five quality parameters were examined: color, pH, firmness, mold growth, and odor. Noodle color was measured immediately after cutting into strands, following a 30 min rest period just before cooking, immediately after cooking, and 30 min after cooking. Noodle color was determined again after 24- and 48-hr holding at 25°C. Noodle pH was determined before and after cooking, and again at 24- and 48-hr intervals. Firmness was determined after the cooked noodles had rested 30 min, whereas examination for mold growth and odor was done after 24 and 48 hr only.

Color

Noodle color was measured as described by Dick et al (1986). A sample containing approximately 45 g of the raw or cooked noodles was placed in the sample cup, care being taken to ensure that the bottom surface was fully covered with noodles with no gap showing. Color of the noodles was a measure of the percent reflectance using the M-500A Agtron color meter calibrated with disks 63 and 85 in the green mode.

pH

A 10-g sample of partially cooked noodles was placed in a Waring Blendor (Waring Corporation, Hartford, CT) and blended for 1 min with a portion of 110 ml distilled water. The slurry was transferred to a beaker, and the residue was rinsed and transferred with the remaining portion of the water. The pH of the mixture was taken at 25°C with continuous stirring. The mean of duplicate readings is reported.

Firmness

The cooked noodles were tested for firmness following a 30-min rest (Dick et al 1986). Firmness was measured using the Instron Universal Testing Machine model 1000 (Instron Corporation, Canton, MA) equipped with a model CE-1 universal cell (Food Technology Corporation, Rockville, MD), a close tolerance piston, and an extrusion grid. Testing parameters used included a crosshead drive speed of 100 mm/min, a chart speed of 50 mm/min, and a force range of 100 kg full scale. The resistance offered by a fixed weight of noodles (75 g) to the piston was recorded graphically on the chart. Peak height (cm) was a measure of firmness. All trials were done in duplicate.

Mold Growth

The noodles were examined in their polyethylene bags for indications of mold growth by two trained judges. The panelists looked for signs of slimy surface, pitted surface, patches of discoloration, and fungal growth. An arbitrary scale of 0 to 5 was designed with 0 for no growth and 5 for objectionable infection. The noodles were scored at 24 and 48 hr after cooking. Samples receiving a score of 3 or higher were discarded and not tested for other quality parameters.

Odor

The noodles were scored for their odor by two trained panelists using an arbitrary scale ranging from 0 to 5. The lower end of the scale denoted samples with acceptable odor, whereas a score of 3 and above meant rejection of the sample.

Statistical Analysis

The ranges and intervals of experimental parameters for response surface methodology (RSM) followed the designs of Box and Behnken (1960) and Box and Wilson (1951). The Statistical Analysis System (Barr and Goodnight 1982) was used to analyze the data. In RSM, the independent variables are denoted along the x- and y-axes with the dependent variable along the z-axis.

RESULTS AND DISCUSSION

Two brands of flour, designated A and B, were selected for this study following preliminary testing of 10 commercial brands of flour of various origins in Southeast Asia. These two flours were typical noodle flours and served as references upon which to base future test comparisons.

Determination of optimum formulation of even relatively simple foods such as Chinese wet noodles is difficult because of the diversity in the properties of the ingredients and the interactions that occur when they are used together. The model system (at variable concentrations of the ingredients) used in our experiments provided valuable information about the role and the level of the ingredients studied in defining the noodle quality characteristics examined.

Table I summarizes the significant terms from the analysis of variance. Sodium carbonate affected all the properties of the cooked noodles; protein level affected firmness whereas sodium chloride had little influence on the noodle quality parameters examined. Among the interaction terms, the only significant ($P < 0.01$) contribution to any noodle quality parameter was that of sodium carbonate and protein content on color. Table II summarizes the regression equations expressing wet noodle characteristics in terms of the experimental variables. The measure-of-fit values for color, pH, and firmness were good to excellent ($R^2 = 0.81$, 0.94, and 0.58, respectively), whereas those for mold ($R^2 = 0.11$) and odor ($R^2 = 0.20$) were poor.

A contour plot of the color of the partially cooked noodles is shown as a function of flour protein and sodium carbonate (Fig. 1). Increasing concentration of alkali was accompanied by decreasing Agtron reflectance values indicating an increase in the yellow (the complement of green) color of the noodles. The regression equation in Table II and the curves in Figure 1 show that the noodle color is mainly affected by the sodium carbonate, and, to some extent, by the flour protein. The noodles became deeper in yellow color as the amount of sodium carbonate was increased (significant at $P < 0.001$). The increase in noodle color due to the alkaline-protein interaction was also significant ($P \leq 0.01$). The development of yellow color in the dough at an alkaline pH is attributed to the flavonoid pigments present in the flour (Fortmann and Joiner 1971).

Moss (1982c) reported that yellowness in noodles is influenced by wheat varietal characteristics and that the color of the noodle deteriorates with increasing protein levels. In the flour samples examined for the response surface study, the protein range was 10.5 to 12.7% (reported on a 14.0% moisture basis). In this range, the detrimental effect on the color of the noodles due to an increase in protein is negligible. In the case of wet noodles, the partial boiling step appears to inhibit the darkening observed in raw noodles (with and without egg) upon aging.

Figure 2 is a contour plot of the pH of the partially cooked noodle as a function of flour protein and sodium carbonate. The cooked noodles had a pH range of 6–10 with the absence and presence, respectively, of sodium carbonate in the formulation. At a sodium carbonate level below 1.5%, noodle pH did not change appreciably with the change in sodium chloride and protein levels. This is probably due to the buffering capacity of the flour proteins. Among the variables studied, the regression equations in Table II show the level of sodium carbonate to be the only factor to have a significant effect on noodle pH ($P < 0.001$).

TABLE I
Significant Terms[a] (F values) from Analysis of Variance

Independent Variable[b]	Color	pH	Firmness
Linear			
A	3.2761	0.1089	16.5649***
B	3.0276	0.2704	0.6241
C	18.9225***	17.9776***	4.4521*
Quadratic			
A^2	3.0276	0.1156	15.8404***
B^2	0.0529	0.9801	0.1296
C^2	28.9444***	38.5641***	6.3001*
Interaction			
$A\times B$	3.4969	0.5776	0.7225
$A\times C$	7.7841**	2.1316	2.2201
$B\times C$	1.5876	0.0081	0.6400

[a] *** = Significant at $P < 0.001$; ** = significant at $P < 0.01$; and * = significant at $P < 0.05$.
[b] A = protein, B = sodium chloride, C = sodium carbonate.

TABLE II
Best Selected Prediction Equations for Wet Noodle Quality Parameters Obtained by Response Surface Regression Procedure and the Measure-of-Fit of Data

Wet Noodle Quality	Equation[a]	R^2
Color[b]	$319.31 - 17.26A + 0.92AC + 0.82C$	0.81
pH[b]	$1.93 + 1.57C - 0.09C^2$	0.94
Firmness[b]	$11{,}647.21 - 1{,}859A + 145.08C + 78.29A^2 - 6.64C^2$	0.58

[a] A = protein, C = sodium carbonate.
[b] Significant at $P < 0.001$.

The firmness of the partially cooked noodles is shown as a function of protein and sodium carbonate in Figure 3 at the medium level of salt. Figure 4 shows the firmness of partially cooked noodles as a function of protein and salt with the sodium carbonate held at the medium level. The regression equation in Table III shows that protein level (significant at $P < 0.001$) and sodium carbonate (significant at $P < 0.05$) contribute to noodle firmness. This is contrary to the report by Dexter et al (1979) that salt at the 2% level appears to strengthen dough properties as reflected by an increase in the farinograph mixing time and decrease in the tolerance index.

The present study showed the effect of salt on the firmness of partially cooked noodles to be insignificant. This can perhaps be attributed to these reasons: 1) The response surface study used a narrow range for the sodium chloride levels in the model. 2) The firmness of partially cooked noodles, although a good indicator of relative strength, is not necessarily a complete measure

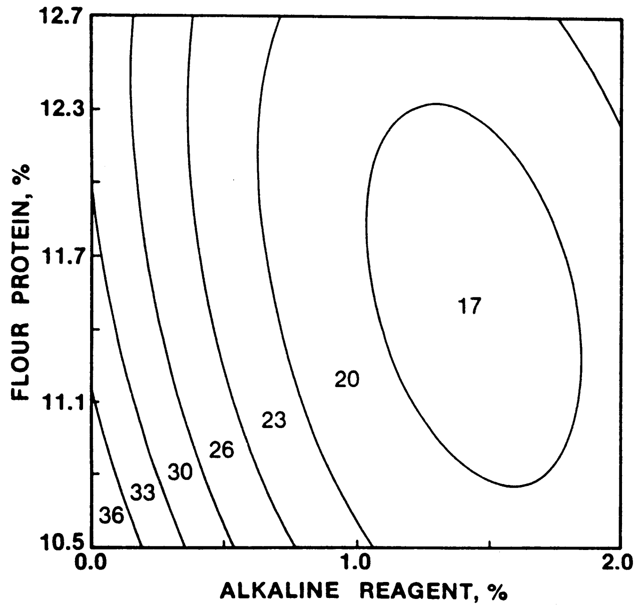

Fig. 1. A contour plot of the color using the Agtron color meter (% reflectance) of partially cooked noodles as a function of flour protein (%) and sodium carbonate (alkaline reagent) (%) at the medium level of sodium chloride.

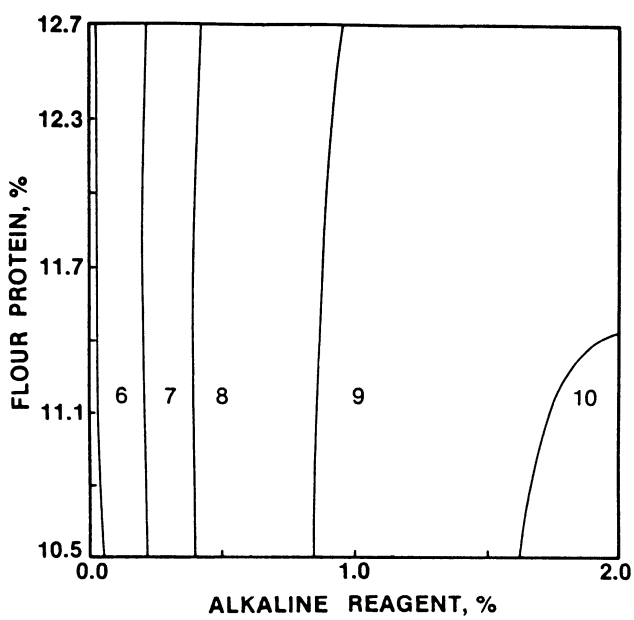

Fig. 2. A contour plot of the pH of partially cooked noodles as a function of flour protein (%) and sodium carbonate (alkaline reagent) (%) at the medium level of sodium chloride.

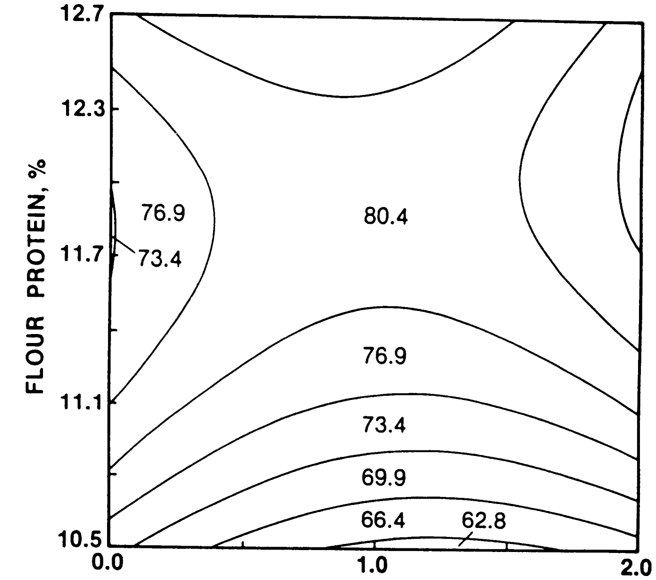

Fig. 3. A contour plot of the firmness (kg-force) of cooked noodles as a function of flour protein (%) and sodium carbonate (alkaline reagent) (%) at the medium level of sodium chloride.

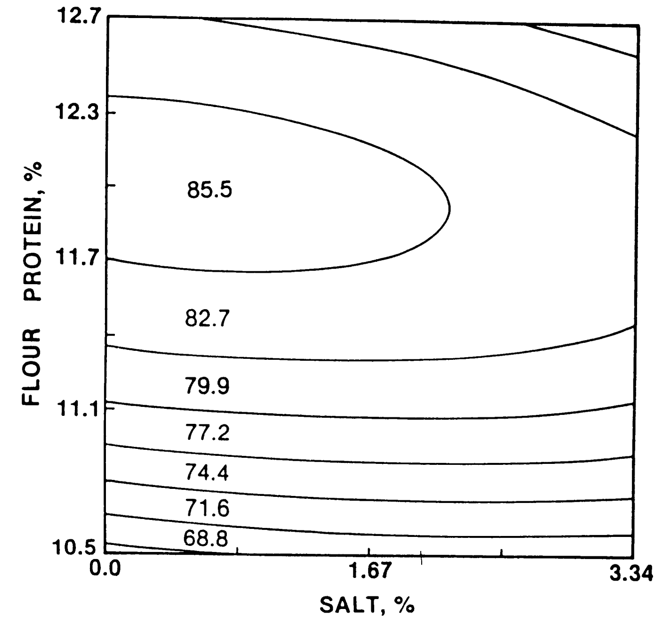

Fig. 4. A contour plot of the firmness (kg-force) of partially cooked noodles as a function of flour (%) protein and sodium chloride (salt) (%) at the medium level of sodium carbonate.

of noodle strength and, therefore, of dough strength. 3) Other phenomena such as surface stickiness, noodle compressibility, and recovery were not measured in this study and may contribute to noodle strength.

Figure 5 was obtained by superimposing the previous three contour maps (Figs. 1–3) and the crosshatched area shows a noodle formulation that might be expected to produce Chinese wet noodles of good quality. The limits of acceptability used to arrive at this range were derived from preliminary scoring of several formulations by a trained panelist—a noodle consultant from Southeast Asia. The noodles of acceptable quality had color values in the 20–40% range (Agtron color meter, green mode) alkaline pH in the range 9–11 and universal testing machine firmness above 70.0 kg-force for the partially cooked noodles. Figure 5 shows that optimum quality Chinese wet noodles could be made in the laboratory from a wheat flour in the protein range 10.0–11.5%, using 1.4–1.7% sodium chloride and 0.7–1.2% sodium carbonate.

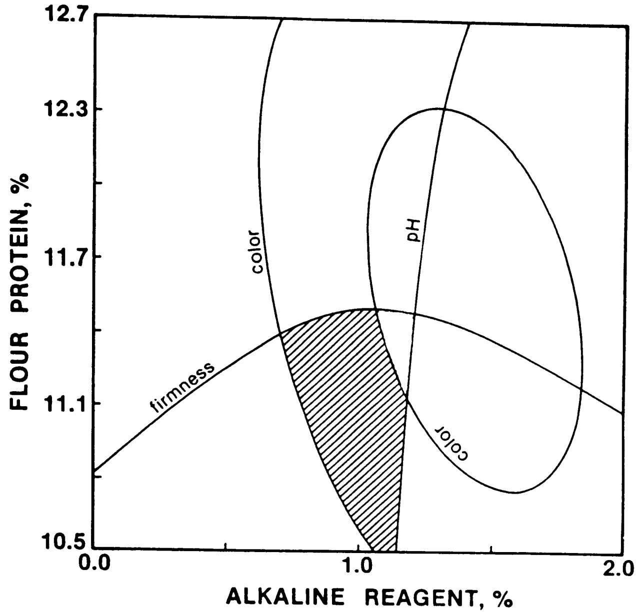

Fig. 5. The optimum (crosshatched) area obtained by overlapping the contour plots of partially cooked noodle quality parameters as a function of flour protein (%) and sodium carbonate (alkaline reagent) (%).

The optimum formulation required to produce the noodles fell within the central region of the experimental design, which was replicated 10 times to check for inherent variance in the technique.

CONCLUSIONS

The study showed that Chinese wet noodles of acceptable to excellent quality can be made from a wheat flour in the 10.0–11.5% protein range, using 1.4–1.7% salt and 0.7–1.2% sodium carbonate. The study also indicated that three attributes of noodle quality—color, pH and firmness—were significantly ($P < 0.001$) affected by sodium carbonate. Protein level in the flour affected color and firmness significantly ($P < 0.001$). Contrary to reports in the literature (Dexter and Matsuo 1979; Dexter et al 1979; Moss 1982a,b), sodium chloride (up to 3.34%) was shown to have no significant effect on any of the attributes mentioned.

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LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 44-15, approved October 1975, revised October 1981; Method 46-11A, approved October 1976, revised October 1982. The Association: St. Paul, MN.

BARR, A. J., and GOODNIGHT, J. S. 1982. Statistical Analytical System. North Carolina State University: Raleigh, NC.

BOX, G. E. P., and BEHNKEN, D. W. 1960. Some new three level designs for the study of quantitative variables. Technometrics 2:455.

BOX, G. E. P., and WILSON, K. B. 1951. On the experimental attainment of optimum conditions. J. R. Stat. Soc. Ser. B 13:1.

COCHRAN, W. G., and COX, G. M. 1971. Page 335 in: Experiment Design, 2nd ed. John Wiley and Sons, New York.

DEXTER, J. E., and MATSUO, R. R. 1979. Effect of starch on pasta dough rheology and spaghetti cooking quality. Cereal Chem. 56:190.

DEXTER, J. E., MATSUO, R. R., and DRONZEK, B. L. 1979. A scanning electron microscopy study of Japanese noodles. Cereal Chem. 56:202.

DICK, J. W., SHELKE, K., HOLM, Y. F., and LOO, K. S. 1986. The effect of wheat flour quality, formulation and processing on Chinese wet noodle quality. Report to the U.S. Wheat Associates, Suite 801, 1620 Eye Street, NW, Washington, DC 20006.

DRAPER, N. R., and SMITH, H. 1981. Page 171 in: Applied Regression Analysis, 2nd ed. John Wiley and Sons, NY.
FORTMANN, K. L., and JOINER, R. R. 1971. Wheat pigments: Flour color. Page 493 in: Wheat: Chemistry and Technology. Y. Pomeranz, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.
MOSS, H. J. 1971. The quality of noodles prepared from the flours of some Australian wheats. Aust. J. Exp. Agric. Anim. Husb. 11:243.
MOSS, H. J. 1982a. Wheat Flour Quality for Chinese Noodle Production. Bread Research Institute of Australia, North Ryde, New South Wales.
MOSS, H. J. 1982b. Wheat flour quality requirements for Chinese noodle production. Page 234 in: Proc. Singapore Inst. Food Sci. Technol. Conf.
MOSS, H. J. 1982c. Quality Requirements for Noodle Flours. Bread Research Institute of Australia, North Ryde, New South Wales.

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