Effects of Cooking Water Composition on Stickiness and Cooking Loss of Spaghetti[1]

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ABSTRACT

The effects of cooking water composition on stickiness and cooking loss of spaghetti made from durum and common wheat were examined using seven cooking waters varying in mineral content. Water hardness was calculated as 1.7–512 ppm of $CaCO_3$. With the exception of deionized water, all cooking waters had values around pH 7.7. Regardless of the cooking water used, spaghetti made from common wheat was stickier than spaghetti made from durum wheat, and both were stickier when cooked in tap, well, or formulated waters (F3 and F4). The two spaghetti types showed similar cooking losses, except when cooked in well water. Spaghetti made from durum wheat did not appear to be as affected by the hardness of the well water as the spaghetti made from common wheat. These findings confirm the need to use a standardized cooking water when comparing results from one test session to another or from one laboratory to another.

Surface stickiness, amount of rinsed material collected from the strands, and cooking loss of spaghetti are influenced by a number of factors including cooking water characteristics, pasta-to-cooking water ratio, and uniform cooking temperature (Menger 1979). Standardized methods would ensure that differences observed between pasta samples are not caused by variations in cooking procedures. Pasta-to-cooking water ratio and uniform cooking temperature are relatively easy to standardize, whereas standardizing cooking water characteristics is more difficult.

Several workers have shown that, with increased water hardness, cooked spaghetti has higher stickiness values (Menger 1980, D'Egidio et al 1981, Dexter et al 1983b, Seibel et al 1985), higher total organic materials in the rinse and cooking waters (D'Egidio et al 1981, Seibel et al 1985), and higher cooking losses (Dexter et al 1983b). High levels of calcium and magnesium in the cooking water can adversely affect spaghetti cooking quality (Menger 1980, Oh et al 1985). Sodium also has a minor effect on surface characteristics of spaghetti (Menger 1980, Seibel et al 1985), although D'Egidio et al (1981) reported no effect.

Other workers have demonstrated the importance of cooking water pH on cooking quality of pasta. Alary et al (1979) and Abecassis et al (1980) decreased surface disintegration and stickiness and lowered cooking losses of spaghetti by adjusting the pH of mineral water to 6.0. Abecassis et al (1980) also adjusted the pH of distilled water and found that spaghetti cooking quality peaked at pH 6. On either side of this pH, quality declined. Seibel et al (1985) found that weakly acidic cooking water gave good sensory quality and decreased total organic materials levels. Oh et al (1985) reported that surface firmness of noodles decreased rapidly and cooking losses were increased at greater than pH 8. Surface firmness and cooking loss were not affected at pH 6–8. In reviewing the work of Chung et al (1978) and Cherry (1982), Feillet (1984) concluded that, at an acidic pH, protein molecules are positively charged and starch molecules are negatively charged. Under these conditions, electrostatic interactions between proteins and gelatinized starch readily occur, enhancing starch-protein interactions. In a basic medium, both protein and starch are negatively charged; therefore, few interactions develop. Thus, at pH 6, the cooking water favors starch-protein interactions, preventing the leaching of starch into the cooking medium.

Ideally, the cooking water used in the assessment of spaghetti cooking quality characteristics should be typical of what is used in the marketplace and permit discrimination between samples. Using distilled water or water at pH 6 is not recommended because it might not allow adequate discrimination between spaghetti samples. Using artificially hardened water is a practical solution because local water supplies differ from region to region and may fluctuate from season to season. Only two formulations have been published for the preparation of artificially hardened water (Dexter et al 1985a, ISO 1985). Limited information is published on prepared hard water, despite the need for a standardized prepared water for cooking spaghetti. Therefore, this study was undertaken to determine the effects of cooking water composition on stickiness and cooking loss of spaghetti and to determine whether spaghetti made from common wheat behaves the same as spaghetti made from durum wheat to changes in cooking water composition.

MATERIALS AND METHODS

Selection and Preparation of Cooking Waters

Seven types of water were selected for study: tap, deionized, well, and four formulated waters. The well water was obtained from a community a few kilometers north of Winnipeg, Canada (Middlechurch, MB). The deionized water was obtained by distillation, deionized by reverse osmosis, and passed through a series of columns (Millipore Corp., Belford, MA) including prefiltration, charcoal, ion-exchange, and final filtration. The tap, well, and deionized waters were analyzed for mineral content using standard methods of determining water quality (American Public Health

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Association et al 1985) by W. M. Ward Technical Services Laboratory (Winnipeg).

The first formulated water (F1) was developed by Dexter et al (1985a) for their cooking quality screening program. The second formulated water (F2) represents a 1:1 dilution of the F1 water with deionized water; it was included to get a range of mineral concentrations in the waters. The other two formulated waters (F3 and F4) were included because, in the preparation of the F1 water, a substantial amount of $6M$ H_2SO_4 had to be added to dissolve the precipitate that developed, requiring the addition of $1M$ NaOH to adjust the pH to 7.5. This raised the question of whether or not the water had the desired hardness. F3 and F4 waters substituted dihydrous $CaCl_2$ for anhydrous $CaCl_2$, which permitted the use of $1M$ H_2SO_4 for pH adjustment only. The level of $NaHCO_3$ was reduced in the F4 water because the level of Na in the F1 water seemed unnecessarily high. The mineral composition of tap, well, and the four formulated waters is presented in Table I. Table II provides information on the chemicals used to prepare the formulated waters.

Sufficient quantities of all cooking waters were obtained before experimentation to ensure that any differences observed were not due to any day-to-day variations in the water quality of the deionized, tap, and well waters, nor to any variations in the preparation of the formulated waters.

Cooking and Testing

Two types of commercial spaghetti were cooked in each of the seven waters: durum semolina (12.7% protein [N $\times$ 5.7], 0.77% ash, 14% moisture basis) and unbleached wheat flour (11.9% protein, 0.39% ash). They represented the range of spaghetti quality available in the marketplace and permitted a comparison of the effects of cooking water composition on spaghetti made from durum and nondurum wheat.

Spaghetti (7 g in 5-cm strands) was added to 175 ml of rapidly boiling water. Samples were cooked in 250-ml glass beakers on ceramic hot plates. Spaghetti samples were cooked until the center core in the strands disappeared. After cooking, the spaghetti was drained and assessed for stickiness using the Grain Research Laboratory compression tester adapted for spaghetti as described by Dexter et al (1983a). A compression force of 24,000 N/m^2 was used to improve precision as recommended by Dexter et al (1985b). Spaghetti strands, unrinsed after draining, were assessed for stickiness 7 min after cooking. Other textural properties such as firmness, compressibility, and recovery were not measured; Dexter et al (1983b) found that these parameters were not influenced by cooking water.

Cooking loss was determined by freeze-drying the recovered water, 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 percentage of spaghetti cooked.

Eight cooking replications were completed for each spaghetti type in each cooking water. Four cooking replications of each spaghetti type in one water treatment was assessed per day, requiring 14 days to complete this experiment.

Statistical Analysis of Data

Analysis of variance was used to determine the significant effects of spaghetti type and cooking water treatment on stickiness and cooking loss (SAS 1988).

TABLE I
Mineral Composition (ppm) of Cooking Waters

Water	Ca	Mg	Na	K	SO_4
Tap	24.20	7.46	2.47	...	3.40
F1	28.96	3.11	82.41	11.64	14.32
F2	14.48	1.55	41.20	5.82	7.16
F3	32.58	3.59	93.14	13.49	16.55
F4	32.58	3.59	72.60	13.49	16.55
Well	93.00	68.00	153.00	...	170.00

TABLE II
Chemical Composition (g/L) of Prepared Cooking Waters

Chemical	Water F1	F2	F3	F4
$CaCl_2$	0.080	0.040	...	...
$CaCl_2 \cdot 2H_2O$	...	...	0.120	0.120
$MgCl_2 \cdot 6H_2O$	0.026	0.013	0.030	0.030
K_2SO_4	0.026	0.013	0.030	0.030
$NaHCO_3$	0.133	0.067	0.150	0.075
Na_2CO_3	0.106	0.053	0.120	0.120

RESULTS AND DISCUSSION

Cooking Water Composition

The pH and calculated hardness for each of the seven waters are provided in Table III. The waters were included in the study based on similarity in pH and differences in hardness. With the exception of the deionized water, all waters had pH values around 7.7. The water hardness range was 1.65–512 ppm of $CaCO_3$. Using the Bigelow and Stevenson (1923) classification, based on $CaCO_3$ level, the deionized and F2 waters were classified as soft; the tap, F1, F3, and F4 waters were classified as slightly hard; and the well water was classified as very hard.

Effect of Water Composition on Stickiness

Significant main effects of treatment and cooking water and a significant interaction of treatment and cooking water were observed for stickiness (Table IV).

As expected, spaghetti made from common wheat was stickier than spaghetti made from durum wheat, regardless of the cooking water used (Fig. 1A). For both spaghetti types, the highest stickiness values were found for tap, well, F3, and F4 waters. The lowest stickiness values were found for the deionized and F2 waters. The F1 water gave spaghetti of intermediate stickiness. These results support those of Menger (1980), Seibel et al (1985), D'Edigio et al (1981), and Dexter et al (1983b), who reported stickier spaghetti with harder water. However, unlike the study

TABLE III
Calculated Hardness and pH of Cooking Waters

Water	Calculated Hardness (ppm $CaCO_3$)[a]	pH
Deionized[b]	1.65	6.1
Tap	91.20	7.7
F1	85.12	7.7
F2	42.56	7.7
F3	96.12	7.8
F4	96.12	7.6
Well	512.00	7.6

[a] Hardness, mg equivalent $CaCO_3/L$ = 2.497 (Ca mg/L) + 4.118 (Mg mg/L) (American Public Health Assoc. et al [1985]).
[b] Values from Dexter et al (1983b).

TABLE IV
Analysis of Variance for Stickiness and Cooking Loss Measurements

Parameter	Source	df	Mean Square	*F* value	*P* value
Stickiness	Water (W)	6	486739.58	27.50	0.001
	Day (Water)	7	17701.79	0.88	0.567
	Type (T)	1	7354375.00	363.92	0.001
	W $\times$ T	6	154085.42	7.63	0.009
	T $\times$ Day (Water)	7	20208.93		
	Error	84	8895.24		
Cooking loss	Water (W)	6	19.34	33.75	0.001
	Day (Water)	7	0.57	0.32	0.924
	Type (T)	1	16.71	9.22	0.019
	W $\times$ T	6	22.58	12.47	0.002
	T $\times$ Day (Water)	7	1.81		
	Error	84	0.46		

by Dexter et al (1983b), the well water used in this study did not yield stickier spaghetti than the tap water, despite the large difference in water hardness. This suggests that water hardness alone does not account for the effects on spaghetti quality. The well water used in Dexter et al (1983b) was slightly more alkaline (pH 8.0) than the well water used in this study (pH 7.6), which could account for the discrepancy in the findings between the two studies. Alkalinity has also been shown to have a deleterious effect on spaghetti stickiness (Alary et al 1979).

Water Composition and Cooking Loss

As with stickiness, significant main effects of treatment and cooking water and a significant interaction of treatment and cooking water were observed for cooking loss (Table IV).

The two spaghetti types had similar cooking losses in all cooking waters except well water (Fig. 1B). The hardness of the well water did not appear to affect cooking loss in durum spaghetti. As with stickiness, these results do not agree with those of Dexter et al (1983b), who observed higher cooking losses for durum spaghetti cooked in well water than in tap water. This may be partly explained by the differences in pH of the well waters used in the two studies. Alary et al (1979) was able to reduce the cooking loss of durum spaghetti cooked in mineral water by lowering the pH. In addition, the Ca level of the well water used in this study was higher than the Ca level of the well water used in Dexter et al (1983b) (93 vs. 80 ppm). This may be significant because Menger (1980) found that Ca lowered pH during cooking.

In contrast, common wheat spaghetti had a much higher cooking loss when cooked in well water. This result alone possibly accounted for the significant treatment main effect.

Kim et al (1989) observed that spaghetti made from durum wheat, when cooked in distilled water, had higher cooking losses than spaghetti made from hard red spring wheat; when cooked in hard water, these results were reversed. Similarly in our study, spaghetti made from durum wheat, when cooked in deionized water, had higher cooking losses than spaghetti made from common wheat; when cooked in the hardest waters (F3, F4, and well), these results were reversed.

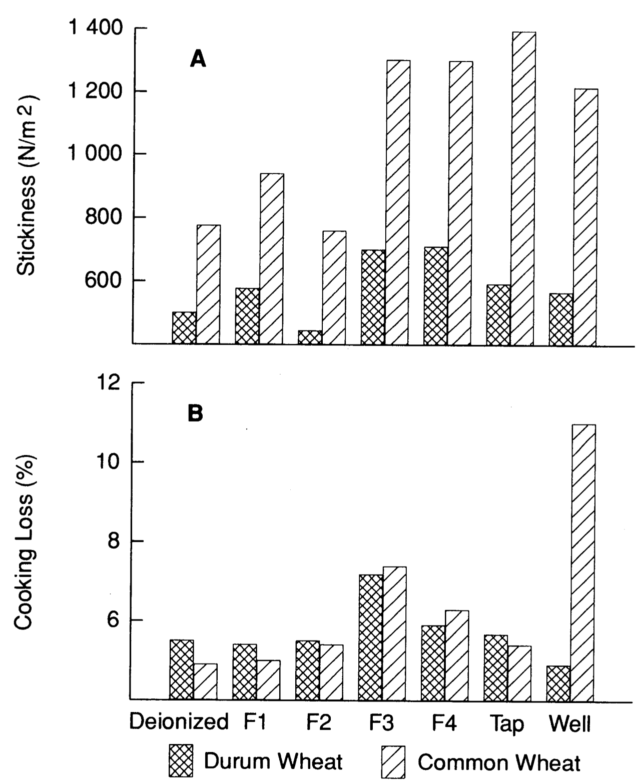

Fig. 1. Two types of spaghetti cooked in seven experimental water compositions: **A,** effect on spaghetti stickiness; **B,** effect on cooking loss of spaghetti.

For both spaghetti types, cooking losses were higher in F3 water than in tap and F4 waters, despite their similarity in hardness (Table III). The only difference between the waters was the higher level of $NaHCO_3$ in the F3 water.

CONCLUSIONS

Cooking loss and stickiness of spaghetti were influenced by the type of water used for cooking. The magnitude of this effect appeared to be influenced by the raw material (durum vs. common wheat) of the spaghetti. This finding supports the observation by Seibel et al (1985) that pasta with inferior cooking quality reacts more strongly to differences in cooking water quality (pH, ion content) than does pasta with higher cooking quality.

Higher stickiness scores correspond with the harder waters, although well water did not produce the stickiest spaghetti. Common wheat spaghetti was stickier than durum spaghetti in any of the cooking waters. Stickiness results of F3, F4, and well water were similar to those of tap water for both types of spaghetti.

The two types of spaghetti had similar cooking losses for all cooking waters except well water. Spaghetti made with common wheat had much higher cooking losses in well water. In contrast, spaghetti made from durum wheat was not affected by the hardness of the well water. For both types of spaghetti, cooking losses in F4 water were similar to those in tap water, but cooking losses in F3 water were much higher than in tap water.

These findings confirm the need to use a standardized cooking water when comparing results from one test session to another or from one laboratory to another. We selected F4 water as the standardized cooking water for future studies. It is slightly hard and has a slightly alkaline pH, which, according to D'Egidio et al (1981), is sufficient to permit discrimination between pasta samples.

Clearly, more work is needed to determine whether pH or mineral composition plays the greater role in influencing spaghetti cooking quality, to investigate the extent to which they influence each other, and to determine how they affect cooked spaghetti quality.

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