EFFECTS OF HOT-HOLDING TIME AND TEMPERATURE ON SENSORY QUALITY AND THIAMIN CONTENT OF SPAGHETTI AND MEAT SAUCE

by

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INTRODUCTION

The effect of home and foodservice practices on sensory and nutritional quality of food is becoming a major concern in our society today. Preparing meals at home is done on a regular basis by most Americans, but there is a growing trend toward eating more meals away from home (Van Dress, 1979). Since the quality of the food being served affects the health and well-being of individuals, this is an important area for investigation. Bengtsson and Dagerskog (1978) stated warm-holding (hot-holding) was a most "effective" means of destroying the quality built into food products by careful choice of raw materials and of processing and storage conditions. If food is not acceptable in appearance, texture and flavor, the consumer will not eat it, which can result in a poor diet. Nutritional quality of the food actually consumed is a concern as well. If quality is lowered by the method of preparation or the hot-holding technique, the food will not provide all the nutrients for our bodies to function properly. Previous research has been done involving hot-holding and its effects on the quality of many different foods. Results of those studies will be compared to the results obtained from this study on spaghetti and meat sauce.

The purpose of this study was to determine the effects of hot-holding time and temperature on sensory quality and thiamin content of spaghetti and meat sauce. The specific objectives of the study were to:

1) Determine the effects of 45, 75 and 105 min hot-holding on the appearance, mouthfeel and texture of spaghetti and meat sauce.

2) Determine the effects of 45, 75 and 105 min hot-holding on the thiamin content of spaghetti and meat sauce.

3) Determine the effects of two different temperatures, 165 and 185°F, on the nutritional, sensory and physical quality of spaghetti and meat sauce.

4) Determine the effects of two different hot-holding methods, household and foodservice, on the nutritional, sensory and physical quality of spaghetti and meat sauce.

This information can be used by foodservice personnel as well as consumers to determine the conditions which are least destructive to the overall quality of spaghetti and meat sauce.

REVIEW OF LITERATURE

Factors influencing the cooking quality of spaghetti

When studying spaghetti and the effects of hot-holding time and temperature on its quality, it is necessary to look at underlying compositional factors which contribute to the quality of spaghetti in order to get an accurate picture of why changes take place. Then it is possible to look at spaghetti quality in relation to what happens during hot-holding with sensory quality and physical measurements.

Protein content. One of the most important factors to consider in pasta production is the type of wheat from which the spaghetti is made. Durum wheat is preferred because of the excellent rheological properties of its dough as well as the superior color and cooking quality it imparts (Dexter and Matsuo, 1978). Previous studies have demonstrated that protein content and gluten characteristics both play an important role in determining spaghetti cooking quality (Dexter and Matsuo, 1977b; Leisle and Baker, 1973). Protein content was the major factor influencing both rheological and cooking properties of durum wheat varieties, and cooking quality and tolerance to overcooking showed continual improvement as protein increased over the complete range of protein content examined for two varieties (Dexter and Matsuo, 1977b). Dahle and Meunchow (1968) found that cooking quality of spaghetti was impaired more by the removal of protein than by the removal of lipids, further supporting the conclusion that protein content is an essential factor in the cooking quality of spaghetti and other pasta products. Using different solvents to extract lipids or protein from spaghetti, they found that the removal of the lipids led primarily to greater stickiness. Removal of both lipid and protein led to stickiness, softness and pastiness. The removal of either component resulted in increased amounts of amylose in the cooking water, and the removal of protein resulted in increased water retention in the cooked spaghetti.

Another study by Matsuo et al. (1972) indicated that samples with a high protein content are firmer, less compressible and more elastic compared to those with a low protein content, which were soft with little elasticity. They stated that protein content should be at least 11% for acceptable cooking quality. Grzybowski and Donnelly (1979) found both protein quantity and quality were significant factors for optimum spaghetti cooking quality. High protein content did not necessarily mean optimum cooking quality. One wheat variety with a protein content of 15.4% had more desirable cooking quality than another variety with 17.6% protein. Protein content and gluten strength have been correlated significantly ($p \leq 0.01$) with cooking loss and cooked firmness, respectively. Cooked firmness of pasta from the variety with 12% protein was significantly lower than for all other samples with protein contents ranging from 13.6 to

17.6%. Protein contents of 15.4, 16.6 or 17.6% produced no significant differences in the cooked firmness values of the pastas. All three pastas were considered at desirable "al dente" levels after 15 min cooking time (Walsh, 1971) and remained so when cooked 20 min. However, pastas from varieties with lower protein contents became soft after 20 min cooking. Matweef (1966) studied two U.S. durum varieties and one French durum variety grown at two locations in France. The protein content was 16% at one location and 11% at the other; the higher protein content produced pasta with better cooking quality.

Dexter and Matsuo (1980) found insoluble residue protein was the Osborne solubility fraction most involved with durum wheat functional properties. Insoluble residue protein also correlated significantly to mean values for gluten intrinsic viscosity, gluten strength, cooking quality and overcooking quality. In addition, Dexter and Matsuo (1979a) tested 18 durum wheat lines and found there was a significant relationship between cooking quality and the proportion of insoluble protein in cooked spaghetti.

Results of a study by Dexter et al. (1978) provided two possible explanations for the importance of protein in determining spaghetti cooking quality. First, a thin protein film envelops the spaghetti strands and the extent to which this film retains its integrity during cooking could affect cooking quality. Secondly, in the cooked region (complete starch gelatinization) the interior structure is composed of a starch-coated protein network. The extent (quantity) and strength (quality) of the protein network may be important in determining spaghetti cooking quality.

Role of gluten development. Grzybowski and Donnelly (1979) indicated cooking times greater than 15 min clearly had a deleterious effect on spaghetti cooking quality, particularly for the low protein, weak gluten samples. Others have shown that gluten plays a significant role in the cooking quality of spaghetti. Sheu et al. (1967) interchanged the components of hard red spring and durum wheat. Cooked spaghetti firmness, cooked weight and cooking losses were affected primarily by the gluten fraction rather than by the starch. Matsuo and Irvine (1970) found a relationship between softer cooked products and weak gluten for a wide range of durum varieties. For the samples they studied, the quality of gluten had a more pronounced effect than the amount of gluten. Semolina farinograms of Grzybowski and Donnelly (1979) correlated with cooking data and clearly indicated the importance of gluten strength. A variety with 15.4% protein had the greatest gluten strength and most desirable cooking quality of all varieties studied.

Hollinger (1963) investigated the influence of the amount of gluten on the cooking quality of spaghetti using the Buhler bending stress tester. Gluten isolated from Canadian hard red spring wheat was added in increments to starch or soft wheat flour to give a protein range from 5-26%. Increasing the amount of gluten in the spaghetti decreased the amount of residue in the cooking water and increased the force required to produce a given extension in cooked spaghetti as measured on the bending stress tester.

Apparently varieties with strong glutens have more reactive sulfhydryl (-SH) groups and a greater probability of an interchange reaction. Thus varieties with higher ratios of reactive -SH to total -SH groups have superior cooking quality (Matsuo and Irvine, 1975). Fabriani (1974) stated that the ratio of reactive to total -SH groups is related to cooking quality; the higher the ratio the better the cooking quality. Dexter and Matsuo (1977c) tested for reactive and total -SH levels in three durum wheat semolinas and a farina, but found the results to be inconclusive.

Gliadin-glutenin ratios as related to spaghetti quality. Walsh and Gilles (1971) also found high spaghetti firmness was associated with high glutenin, low gliadin content. According to their chromatographic data, the varieties with high levels of glutenins and albumins had good cooking quality. Dexter and Matsuo (1977a) suggested that a threshold level of glutenins must be present for satisfactory cooking quality; amounts greater than this imparted only a limited improvement in cooking quality. Wasik and Bushuk (1975) further found it possible to rank 14 wheat varieties on the basis of the glutenin:gliadin ratio and this was essentially the same order as established by rheological and cooking tests.

Starch content. Frey (1970) reported that starch played an important role in the consistency and water absorption of pasta products and that pregelatinized wheat and potato starches could be used to replace protein to make acceptable quality spaghetti. He also found that egg white proteins surpassed the effect of vital wheat gluten on pasta consistency. Dexter and Matsuo (1979b) found cooking quality deteriorated as the proportion of waxy maize starch was increased and amylose content was decreased. A high proportion of waxy maize starch resulted in low resilience as reflected by the compression test. The amylopectin-rich gels, with their high fluidity, were not severed easily by the blade during the tenderness index test. The amylopectin resulted in an undesirable pasta texture since a firm, resilient cooked product is preferred. Increased amylomaize content resulted in firmer cooked pastas as evidenced by decreases in the compressibility and tenderness indexes (Dexter and Matsuo, 1979b). The cooking quality improvement brought about by the enrichment of the blends with amylomaize starch was not nearly as great as has been achieved by the manipulation of gluten proteins (Dexter and Matsuo, 1977b, 1978; Matsuo et al., 1972; Matsuo and Irvine, 1970; Sheu et al., 1967).

Tests to predict spaghetti making quality. Researchers have studied various tests available to determine which would be most helpful in predicting the spaghetti making quality of the wheat variety. Data from Dexter et al. (1980) indicated that screening tests based on the SDS-sedimentation test and wheat protein would be adequate for comparing durum wheats for gluten strength and spaghetti cooking quality. Kosmolak et al. (1980) indicated that determining gliadin electrophoretic patterns of segregating durum wheat lines would be a useful technique for eliminating lines with undesirably weak gluten strength based on the relationship they found between gliadin patterns and durum wheat gluten quality.

Irvine et al. (1961) found that the farinograph may be useful as a control instrument for commercial macaroni processing. The curve characteristics were influenced to a greater extent by wheat type and durum variety. Two principal types of farinograms were those with a high and low tolerance index. High tolerance index values are associated with good durum varieties, reasonably high protein content and homogeneous particle size; low values are obtained from wheats other than durums, low protein samples, poor durum varieties or heterogeneous semolina. Dough development time is influenced most noticeably by wheat type and variety but also varies with absorption and temperature; low protein and low grade may lengthen dough development time. Their results suggest that changes in various semolina qualities are reflected by typical changes in farinograms.

Good cooking quality in spaghetti is related to gluten quality, but this is only one factor involved. Other areas such as the role of starch in spaghetti quality and the effect of other constituents like soluble and insoluble pentosans on spaghetti quality should be researched thoroughly (Matsuo and Irvine, 1975).

Instrumental measurements of spaghetti texture

The texture of cooked spaghetti is one of the most important quality attributes (Wasik, 1978), therefore reliable methods of instrumental measurement are desired. Research using various instrumental methods to measure the texture of cooked spaghetti will be examined.

Ottawa Texture Measuring System. Voisey (1971) described a versatile instrument for use in measuring the texture of foods. The Ottawa Texture Measuring System (OTMS) is based on a simple screw-operated press which accommodates a range of different test cells. Force, deformation and time during the test are recorded with electronic apparatus. Voisey and Larmond (1973) used the OTMS with various test cells attached to measure spaghetti texture. The test cells used were the wire extrusion cell, the plate extrusion cell and the wire shear cell. With the wire extrusion cell a loose-fitting piston was driven into a box containing the sample to compress, shear and extrude it through a wire grid in the bottom. A 20 cm^2 plate extrusion cell uses a plate with 83 holes, 4 mm diameter, equally distributed over its area to replace the wire grid. The wire shear cell has 10 parallel 1.59 mm diameter wires which are driven into a slotted container at 10 cm/min to compress and shear the sample. Sample size was determined by weight.

A double shearing fixture was arranged to fit the press of the OTMS. A single stick was placed in semicircular grooves in two blocks and clamped in position by two blocks with matching semicircular grooves. A bar between the blocks had a slot through which the stick also passed. The bar was suspended from the crosshead load cell which was raised at 5 cm/min to shear the stick on either side of the bar, and force vs time recorded. In the double shear cell, the force built up linearly as the sample was compressed to a peak which coincided with the rupture of the sample and was followed by a rapid decrease. Slope was related to firmness and the maximum force related to cohesiveness.

In the plate extrusion, wire extrusion and wire shear cells, the force initially built up nonlinearly with deformation (time) as the spaghetti was packed into the cell. This was followed by an approximately linear portion as the packed mass was compressed. An abrupt peak which was observed to coincide with the onset of sample shearing and extrusion then occurred. The force at this peak provides an index of the shearing or rupture resistance of the sample, that is, the cohesiveness, and the slope of the linear portion is related to the elastic properties or firmness (Szczesniak, 1963). There followed a period when the force fluctuated randomly about an approximately constant value, a plateau, until deformation stopped, indicating that shearing and extrusion took place at approximately constant conditions. The average plateau force is related to firmness and cohesiveness.

According to Voisey and Larmond (1973) a number of readings can be taken from the curves depending on the type of cell used: a) slope--elasticity or firmness; b) maximum force--rupture or cohesiveness; and c) energy used in the test--a gross index of textural properties. A preliminary test with six spaghetti varieties cooked for optimum times and a constant time of 12 min indicated that slope, plateau, and maximum forces ranked the varieties in the same order. It appeared that the elasticity and rupturing behavior of spaghetti might be related.

Voisey and Larmond (1977) in their work with the OTMS found four types of characteristic shapes as a result of the extrusion of the spaghetti through a wire grid. In all cases, the force built up rapidly the longer the sample was packed and compressed in the cell by the plunger. An abrupt change in slope coincided with the onset of shearing and extrusion through the wire grid. After that point the general characteristic of the curves varied with the different samples. In all the curves there were minor fluctuations about the mean line throughout the test. Interpretation of the shapes in relation to textural characteristics has not been explored fully, but Voisey and Larmond have arrived at some tentative descriptions of the curves. They are: 1) a steadily increasing plateau indicates a resistance to shearing causing the product to be compressed to a greater density before it can be forced through the wires, which indicates a tougher product; and 2) a horizontal plateau is generally indicative of a soft homogenous product that shears and extrudes through the wires under constant stress conditions.

Voisey et al. (1978) studied texture of cooked spaghetti measured instrumentally using the multiblade cutting cell of the OTMS. Instrumental readings showed that spaghetti toughness (maximum force) increased logarithmically with the deformation rate used to cut the sample, and in the range of 2.5 to 155 cm/min the rate selected affected the relationships with sensory evaluations. This suggests that the cutting rate selected is critical and must be constant. The data did not suggest an optimum rate for the test. The toughness changed with cooking time and elapsed time after cooking so these times must be controlled carefully.

Spaghetti Tenderness Testing Apparatus. Matsuo and Irvine (1969) describe an apparatus for measuring the tenderness of cooked spaghetti. To simulate the "bite test" a continuously increasing force is applied to a cutting edge. The loading mechanism of the Buhler bending stress tester was used to apply the uniformly increasing loads. The rate of movement was measured with a linear variable differential transformer. The rate of cutting is recorded and the curves, which are reproducible, are interpreted in terms of a tenderness index. The tenderness index is the slope at the midpoint of the curve. Low values correspond to firm spaghetti and high values to soft spaghetti. For the range of samples studied, results indicate that the apparatus is sufficiently sensitive to differentiate spaghetti made from various varieties and types of wheat.

Matsuo and Irvine (1971) adapted their testing apparatus to measure parameters related to chewing, in addition to the tenderness index. Chewing is essentially compression from which an individual can classify the product as doughy, mushy or "al dente." They obtained parameters related to compressing and the ability of the sample to recover from compression. The cutting blade of the apparatus was replaced by a blunt-edge blade for compression. A strand of cooked spaghetti about 3 cm long was placed in the slot of the sample holder. The beam of the apparatus was adjusted to give a slight positive pressure to the blade so that the "recovery" part of the test will not be influenced. The recorder is turned on and the weight is placed on the end of the beam manually. The entire length of the blade compresses the center portion of the sample and after 15 sec the weight is removed and the curve recorded for another 15 sec. The compression curves obtained were evaluated to determine compressibility and recovery of the sample.

Instron Universal Testing Machine. Szczesniak (1972) discussed different texture measuring devices used in the food industry, and pointed out the popularity of the Instron Universal Testing Machine (IUTM) and the Food Technology Corporation's Texture-Test System (formerly the Kramer Shear Press). These have become increasingly popular as they can serve a number of different purposes since the test cell can be changed depending on the type of measurement desired. Crushing, shearing, puncturing, extrusion, compression and other tests can be easily performed, and the versatility, flexibility and accuracy of these instruments makes them desirable for use in the food industry.

Walsh (1971) measured the firmness of cooked spaghetti using the IUTM. The amount of work required to shear a cooked strand with a special Plexiglass tooth was used as a measure of spaghetti firmness. The area under the force-deformation curve was used as the measure of energy required to cut the sample. The measurements were compared with taste panel data and statistical analysis of the data was performed to characterize spaghetti firmness and determine accuracy of the shear test. The results showed that the texture or "bite" of cooked spaghetti could be measured by determining the amount of work required to shear a cooked strand of spaghetti.

Voisey and Larmond (1973) also used the IUTM and other instrumentation; they indicated the best method to measure cooked spaghetti texture was a multiblade shearing cell that measured the force to shear the sample at 100 places. In the multiblade shearing cell, the force built up linearly as the sample was compressed to a peak which coincided with the rupture of the sample and this was followed by a rapid decrease. The cell is suitable for quality control application since it produces a single numerical value (the maximum force) which is related to consumer reaction, and is sensitive to changes in texture from varietal differences or processing methods. To apply the test, the rate of shearing must be constant, and differences are accentuated as the rate increases.

Additional work was done by Voisey and Larmond (1977) using the multiblade shearing cell. The attachment was designed to be attached to the IUTM where 10 strands were sheared 10 times making 100 cuts. The upper attachment consisted of 10 blades, 1.5 mm thick, inserted into a plate parallel with each other and 1.25 cm between centers. The lower attachment was a plate with 10 parallel slots 2 mm wide corresponding to the blades in the upper component. Ten semicircular grooves were made, transverse to the slots, parallel with each other at 1.25 cm centers to support 10 strands of cooked spaghetti. The crosshead was lowered and drove the 10 blades down through the spaghetti into the slots. The load cell detected the force exerted by the spaghetti in resisting shear and this was recorded against time on a strip chart.

Results from their work showed how the force increased almost linearly with time and, therefore, movement of the shearing blades. The force reaches a maximum and then falls rapidly. They observed that the maximum force coincided with the onset of shear failure of the spaghetti strands which generally sheared in only one plane, on one or the other side of the shearing blades.

Voisey and Larmond (1973) also used a tensile fixture installed in an IUTM to test single spaghetti sticks. A 1.5 cm diameter knurled rod was mounted horizontally on the IUTM base. A second rod, parallel to the lower rod, was suspended from a load cell on the crosshead. Crosshead movement was adjusted so that the initial distance between the rod center lines was 4.0 cm. A stick of cooked spaghetti was wrapped twice around the upper rod and the remainder allowed to hang. The lower end was then wrapped around the lower rod so that there was no tension applied to the stick. The ends of the stick were inserted in slots at the rod ends to increase slippage resistance. The crosshead was raised at 2.5 cm/min until the stick ruptured. The load cell detected the force and a record of force vs time was obtained on a strip-chart.

In the tensile test, the force built up nonlinearly until the stick ruptured abruptly. The maximum force is related to cohesiveness. Rupture consistently occurred in the mid-portion of the spaghetti stick indicating that the rods did not damage the sample and introduce error.

Voisey et al. (1976) studied the effects of different cutting rates and time after cooking on pasta texture using the multiblade shear cell of the OTMS in an IUTM for deformation rates up to 100 cm/min. Engineering Research Service made a second test machine in order to operate the multiblade shear cell at 155 cm/min. Their results indicated that the cooked pasta samples became less tough with increasing time after cooking. The rate of softening was rapid in the first 10 min and then increased at a lower rate over time until approximately 45 min had elapsed. It was suggested by them that the test samples be tested only after 45 min, which would allow the samples to stabilize. Also, it appeared that differences in texture between samples decreased with increasing storage time, which would have a negative influence on sensory evaluation of the samples.

Voisey et al. (1976) indicated that textural changes noted with time after cooking were attributed to moisture migration through the cross section of the spaghetti after cooking was stopped. Optimum cooking time is considered the point at which all the starch across the cross section is gelatinized. There is a considerable moisture gradient across the radius of the strand, with a higher moisture content at the outer surface and a lower one at the center. As a result of this uneven distribution of moisture, there is migration of moisture from the outside of the strand to the center until equilibrium is reached. Since this cannot be stopped, it is essential to present sensory panelists with the samples at a constant time after cooking to get valid results. Both instrumental and sensory tests should be conducted over the same time span in order for the results to be comparable.

They also found a cutting rate increase from 2.5 to 155 cm/min had a large effect on instrumental readings. The maximum rate seemed to optimize the discrimination between samples. There were some instances in which ranking of the samples at one rate did not correspond to ranking at another rate, therefore this procedure was not recommended.

The OTMS wire extrusion cell, attached to the IUTM, was evaluated for use in measuring pasta texture and was found to be unsatisfactory. Samples placed in the OTMS wire extrusion cell were compressed to a solid glutenous mass before rupture, whereas, when spaghetti is consumed the strands are usually bitten individually.

Research done by Voisey and Larmond (1973) indicated that cooking time had a marked effect on the cutting force required in the instrumental test (multiblade shear cell) which decreased nonlinearly with increasing cooking time.

The effect of cooking time on instrumental readings again was investigated by Voisey et al. (1977). Their data indicated that the rate of softening of different samples with increased cooking time is not the same, so the ranking of the samples may be reversed by using different cooking times. Therefore, it was not recommended that a certain cooking time be chosen at random, since the rankings obtained may not relate to the order at the optimum (for eating) cooking time.

Research by Voisey et al. (1977) determined the effect of time after cooking for 20 spaghetti samples. Results were that maximum force and initial rupture force (by multiblade shear cell attached to the IUTM) decreased with elapsed time after cooking. Furthermore, if samples were ranked by the maximum force after the elapsed time period, little variation was found, but a ranking of the initial rupture forces was affected by time after cooking.

Voisey et al. (1977) also determined the repeatability of the readings from the multiblade shear cell by doing replicate tests on the spaghetti samples. Samples were cooked and tested after 5, 15 and 25 min (approximately the same times used in the sensory tests) with a deformation rate of 155 cm/min. Testing was repeated 10 times on each sample. Variation was found in both maximum force readings and in initial rupture force. With maximum force, the variation was acceptable and was most likely attributable to variation inherent in the properties of the spaghetti. Large variations in initial rupture force still were considered acceptable if this characteristic had a close relationship with sensory ratings.

Deformation rate and time after cooking also were varied to determine the effects on the cutting forces. They concluded that deformation rate selected to test the spaghetti by the multiblade shear cell is extremely critical because it affects the magnitude of the force readings and the ranking of samples. The intervals between samples also depend on deformation rate.

Control of test conditions is essential in making comparisons of spaghetti samples according to Voisey et al. (1977). Maximum and initial rupture forces measured by the multiblade shear cell were affected by deformation rate used, so it should be controlled during testing. Discrimination between samples increased with increasing deformation rate. Compression force must be controlled as it influences the measurement of stickiness of spaghetti, especially at forces above those required to cause rupture. Deformation rate used in the tension phase of the stickiness test must be constant. Also, a constant deformation rate must be used in the compression phase of testing in order to precisely control the applied force 30 sec after stopping the crosshead. Stickiness of spaghetti was affected by time after cooking, so timing must be closely controlled to make meaningful comparisons.

Relationship between instrumental and sensory scores

Numerous instrumental systems have been used to measure spaghetti texture. Texture is a complex quality factor which depends on a number of other variables. Mechanical and rheological properties and their relationships to consumer reactions are not fully understood. Therefore, according to Voisey (1971) the only meaningful test of an instrument's accuracy is a direct comparison with sensory analysis. The relationship between instrumental testing and sensory analysis scores will be examined in this section.

In the study by Walsh (1971), the amount of work required to shear a cooked strand with a special Plexiglass tooth attached to an IUTM was measured and compared with taste panel data. The panelists rated firmness of the spaghetti on a scale of 1 to 10 with 1 described as mushy and 10 described as tough. To relate taste panel results to shear measurements, a linear regression equation was computed by setting the panel scores as the dependent variable and work required to shear the spaghetti as the independent variable. The equation was set up as follows:

$$\text{Panel firmness score} = 1.80 \times \text{Instrument value} - 4.01$$

The correlation coefficient for the equation was 0.812, which was significant at the 1% level of confidence. With the regression equation it was possible to convert shear measurements into taste panel scores. The ideal firmness rating by taste panelists (score of 5) corresponded with 5.01 g/cm of shear by the instrumental method. The term "mushy" (score of 1) corresponded with 2.8 g/cm of shear and "tough" (score of 10) corresponded with 7.8 g/cm of shear.

Analysis of Variance (ANOV) showed that replications were not a significant source of variation for the taste panel and the shear test data, which made it apparent that the tests were reproducible. The samples were significant for the shear data and for all but two of the panel members. This indicated that the shear test as well as most of the panel members were able to detect firmness differences among the samples. Also, since all correlation coefficients of panel members vs shear measurements were positive, it was concluded that the panel and the shear test were measuring similar physical properties of cooked spaghetti. Overall, the results of this new instrumental method for measuring the firmness of cooked spaghetti showed that the texture or "bite" of cooked spaghetti could be measured by determining the amount of work required to shear a cooked strand of spaghetti. Statistical analysis of data from replicate determinations showed that the shear test had a high positive correlation with taste panel scores (r = 0.812).

Voisey and Larmond (1973) compared the results from the different cells of the OTMS with the sensory data. They found strong relationships between firmness and chewiness measured organoleptically and by the shear and tensile tests. Firmness was related to tensile force with r = 0.739, and to shear force by the multiblade shear cell, r = 0.815. Correlation coefficients were slightly lower with chewiness as it was related to tensile force, with r = 0.613 and to shear force by the multiblade shear cell, r = 0.712. The higher correlation coefficients for firmness are not unusual since firmness is perceived on the first bite when the consumer may be most sensitive to this mechanical property. Shear and tensile forces were related more strongly to firmness and chewiness than shear and tensile stresses, which indicated that the consumer may react to a combination of size and mechanical properties of the spaghetti. Also, shear measurements were related more strongly than tensile readings to chewiness and firmness since a primary process in masticating spaghetti involves shearing through the sticks. Shear and tensile forces were related strongly (r = 0.907) and stresses to a lesser degree (r = 0.651), indicating some relationship between tensile and shearing properties of the spaghetti. Correlation coefficients between chewiness and wire extrusion cell readings were based on readings from the varieties on which sensory tests were replicated five times as opposed to twice for the other varieties. These correlation coefficients indicated that chewiness was related to energy (r = 0.618), force (r = 0.592) and plateau force (r = 0.581). Voisey and Larmond (1973) speculated that these measurements are a gross indication of the work required to compress, shear and extrude the sample, as would be perceived in continuous chewing.

They indicated the initial rupture measured by the wire extrusion cell is not a shearing motion but is more likely tension applied to the sticks of spaghetti as the spaghetti is bent over the wires. Voisey and Larmond based this conclusion on a significant correlation between the wire extrusion readings and tensile readings. However, no relationship was shown between the shear readings and the wire extrusion readings.

Voisey et al. (1978) measured the texture of spaghetti by sensory analysis and using the multiblade cutting cell of the OTMS. The cutting forces correlated to sensory characteristics of adhesiveness, firmness, springiness and rate of breakdown of the spaghetti in the mouth. Comparison of the sensory and instrumental results showed a relationship between the mean instrumental cutting forces and mean sensory scores for rate of breakdown, springiness and firmness. Rate of breakdown had the strongest association with the OTMS force readings. Scatter diagrams suggested that force readings obtained with the multiblade cutting cell appear to be linearly related to sensory evaluation of cooked spaghetti texture. This was supported by significant correlation coefficients between the two instrumental and four sensory readings in the majority of the comparisons. For example, the correlation coefficient between maximum force and rate of breakdown at a deformation rate of 100 cm/min was $r = -0.84$. The correlation coefficient between rupture force and rate of breakdown was -0.86 at a deformation rate of 2.5 cm/min. Adhesiveness sensed by panelists was related to the cutting forces. A correlation coefficient of $r = 0.65$ was found between adhesiveness and maximum force using 2.5 cm/min deformation rate; between rupture force and adhesiveness, r was 0.62. Correlation coefficients were not affected in any systematic manner by the deformation rate used in the instrumental test which suggests that an arbitrary selection of one constant rate was adequate.

A machine designed for testing spaghetti tenderness called the Grain Research Laboratory (GRL) Spaghetti Tenderness Tester (Matsuo and Irvine, 1969, 1971) was found to be useful in determining textural characteristics of cooked spaghetti. The textural characteristics of a number of spaghetti samples were studied by Voisey and Larmond (1973, 1977) using three methods: a) by trained sensory evaluation; b) by the IUTM; and c) by the OTMS (Voisey, 1971). Samples from the same lot were tested in the apparatus of Matsuo and Irvine (1969, 1971) to establish a relationship between measurements and trained sensory tests. Sensory firmness was judged as the force required to penetrate a substance with the molar teeth. Chewiness was the length of time in seconds required to masticate a sample at the rate of one chew per second in order to reduce it to the consistency satisfactory for swallowing.

Multiblade shear tests were done using the IUTM. Shear force was calculated on the basis of 100 cuts and shear stress was calculated taking into account the cross-sectional area. With the OTMS a sample of spaghetti was compressed and extruded through a wire grid. Readings obtained were the maximum force and plateau force. The GRL Spaghetti Tenderness Tester was used to determine the tenderness index, compressibility and recovery of the samples as described by Matsuo and Irvine (1969, 1971).

Results of the testing procedures indicate that samples giving high values of firmness, chewiness, shear force and shear stress generally yielded low tenderness index and compressibility values, and a high recovery value. Correlation coefficients of parameters of the GRL apparatus to those of the other tests show this trend. A significant negative correlation between tenderness index, as determined using the GRL apparatus, existed with both sensory firmness (r = -0.809) and IUTM shear stress (r = -0.801). Compressibility, as determined by the GRL apparatus, had a significant negative correlation to sensory firmness (r = -0.707) and IUTM shear force (r = -0.953). Recovery, the other parameter determined from the GRL curves, was positively correlated to firmness (r = 0.707), chewiness (r = 0.780) and IUTM shear force (r = 0.832) (Matsuo and Irvine, 1974).

Other research (Klein et al., 1984) done by members of the North Central Regional Research (NC-120) committee with the hot-holding of spaghetti and meat sauce involved both sensory analysis and instrumental analysis. In an early experiment done by Brown and Love (1982) at Iowa State, freshly prepared spaghetti was compared to spaghetti held for 45, 90 and 180 min at 74°C. The sensory firmness scores were as follows: a) freshly prepared, 11.0 (14 = extremely firm, 1 = extremely soft); b) held 45 min at 74°C, 8.3; c) held 90 min at 74°C, 7.5; and d) held 180 min at 74°C, 5.2. The scores showed a definite trend for softening of spaghetti as holding time was increased. The multiblade shear cell was attached to the IUTM which recorded the force to cut 10 strands of spaghetti after holding. The amount of force required to shear the spaghetti decreased the longer it was held, with freshly prepared spaghetti requiring 8.8 kg force, spaghetti held 45 min, 6.2 kg force, spaghetti held 90 min, 5.3 kg force and spaghetti held 180 min, 3.9 kg force. In another experiment by Brown and Love (1982) the spaghetti cooked 14 min and served immediately was judged firmest, 12.4, by sensory evaluation; the spaghetti cooked 15 min and held 60 min at 74°C was next firmest, 7.7; and the spaghetti cooked 30 min and held 120 min at 74°C was scored softest, 3.2, according to the taste panel results. The same trend was evident with the amount of force used in the multiblade shear test. More force was required to shear 10 strands of spaghetti, 7.3 kg force, that were not held than was required to shear the spaghetti cooked 15 min and held 60 min at 74°C, 5.8 kg force, and the spaghetti cooked 30 min and held 120 min at 74°C, 4.4 kg force. The OTMS also was used and it measured the force required to extrude 100 g of spaghetti through a perforated plate. When the spaghetti that was cooked for 14 min with no hot-holding was extruded it required 23.4 kg of force, the spaghetti cooked 15 min and held 60 min at 74°C required 17.4 kg of force, whereas when the spaghetti that was cooked 30 min and held 120 min at 74°C was extruded, it required only 12.2 kg of force, showing a considerable softening of the spaghetti during hot-holding. Sensory analysis scores by the taste panel and readings from the multiblade shear and OTMS from the Iowa study all showed the same trend; the spaghetti became softer the longer it was held and cooked.

Researchers from Michigan State compared sensory scores for firmness and chewiness of freshly prepared and reheated spaghetti (household quantity) with and without soy incorporation, to instrumental readings from the Allo-Kramer Shear Press. The force in lb/g was recorded. Lowest values were from the 20% soy sample reheated by stovetop and microwave (.57 and .56) and the highest from the all beef spaghetti reheated by both methods (.67 and .65). Sensory scores for firmness and chewiness correlated well with some, but not all, readings.

Instrumental measurements were compared by workers at Kansas State to sensory scores for firmness of freshly prepared spaghetti and spaghetti which had undergone 1, 3 and 5 freeze-thaw cycles and 5 immediate freeze-thaw cycles. The force required to extrude the sample through a perforated plate by a plunger, attached to the IUTM, was measured. The freshly prepared spaghetti required the most force. As the samples went through more freeze-thaw cycles, less force was required, except for the samples that went through 5 evenly spaced freeze-thaw cycles.

Voisey et al. (1977) found a low correlation coefficient (r = -0.17) between the stickiness tensile force (obtained by compressing spaghetti between flat plates, attached to the IUTM, and then pulling them apart) and sensory adhesiveness ratings. Possible explanations for lack of correlation that were cited in their work include: a) the range of adhesiveness in the group of samples was insufficient to compare the sensory and instrumental methods; b) the instrumental and sensory readings were not related to the same physical characteristic of the spaghetti; c) the definition of sensory adhesiveness was not satisfactory for the comparison; and d) saliva was not used in the instrumental test so that the adhesion forces were not similar to those in the mouth.

Instrumental stickiness readings (tensile force) and visual tactile assessments were strongly correlated. Visual tactile measurements were obtained by judging: a) the ease of removal of the sample from the beaker; b) the degree of "slump" of the mass of spaghetti after ejection onto a galvanized steel plate; c) the force required to stir and spread the mass with the index finger; d) force needed to separate strands adhering together; and e) the angle of slip down a galvanized steel sheet. The correlation improved when the subjective ratings for three of the characteristics (ease of removal, stirring with finger and ease of separating strands) were summed to provide a composite index. Highly significant correlation coefficients were found between the two instrumental texture readings (maximum force and rupture force) and the four sensory readings (firmness, adhesiveness, springiness, and rate of breakdown).

Cutting forces increased exponentially with deformation rate affecting the intervals between and ranking of the samples for spaghetti texture. Therefore, a constant deformation rate must be chosen. Also, as the deformation rate increased so did discrimination between samples. Spaghetti toughness decreased with cooking time and decreased nonlinearly with time after cooking. Since cooking time and elapsed time after cooking interact together to affect toughness, and therefore ranking, both must be controlled when samples are compared.

Effect of hot-holding procedures on the quality of food

Various hot-holding procedures used in foodservice either before or during serving of the food usually have a detrimental effect on the sensory quality of the food. Acceptable appearance, texture and flavor are vital to the actual consumption of the foods served. Bengtsson and Dagerskog (1978) stated warm-holding (hot-holding) is a most "effective" means of destroying the quality built into food products by careful choice of raw materials and of processing and storage conditions. The results of the several investigations conducted in this area will be presented.

Vegetables. In one study by Karlström and Jonsson (1977), steamed white potatoes held in aluminum foil packages under closed lids at 60, 75 and 90°C, for 1, 2, 3 and 4 hr prior to analysis were compared to freshly steamed potatoes. During hot-holding, the average score for total impression of odor, appearance, flavor and texture decreased rapidly with increasing time. Deterioration was greatest during the first few hours. Average scores also decreased significantly with increasing temperature.

Hill et al. (1977) studied the effects of the cook-freeze method on vegetables. Both fresh creamed potatoes and creamed potatoes made from dehydrated potato powder were prepared and frozen and reheated in the same manner. To reheat, the potatoes were placed in an aluminum tray, covered with a lid and placed in a preheated forced convection oven at 180°C for 25 min. After reheating, the potatoes were placed in a hot storage cabinet maintained at 80°C. Fresh potatoes were held for 15, 30 and 60 min.

Peas were purchased, frozen and reheated in an aluminum container with a lid in a forced air convection oven for 25 min at 180°C. They were held for 30 and 60 min in the same manner as the potatoes. Fresh cauliflower and cabbage were cooked, frozen, reheated and held in the same manner as the potatoes. Also, frozen cauliflower florets were purchased and freezing, storage and hot-holding were the same as for the potatoes. The declared control difference tests indicated that hot storage of fresh creamed potatoes caused significant differences in flavor to be detected even after 15 min of hot storage. In this test, three samples were presented to the panelists. One was labeled "standard" and the others B and C. Panelists were asked to first taste the standard, then the others, and to score each independently on a five-point scale, determining the degree of difference from the standard. The scale was 5 (same as standard) to 0 (extremely different from standard). One of the two samples was always the same as the standard. Creamed potatoes prepared from a dehydrated potato mix were not significantly different in flavor due to hot storage even after 60 min holding at 80°C. Peas had a detectable flavor difference when they were held for 60 min, but not 30 min. Neither cauliflower purchased fresh and frozen nor cabbage showed significant flavor differences when held for 60 min.

Karlström (1982) investigated the sensory quality of green peas handled in a hot-holding system on a laboratory scale. In this study the trays of peas were placed in modified hot-air convection ovens (for temperature control to ± 2°C) and were kept hot at 45, 60 and 75°C for 1, 2 or 3 hr. Samples were evaluated by a semitrained panel for these sensory properties: a) intensity of off-odor; b) total impression of odor; c) intensity of off-flavor; d) total impression of flavor; e) intensity of discoloration; f) total impression of appearance; g) intensity of hardness; h) intensity of pastiness; and i) total impression of texture. For all sensory attributes significant differences ($p \leq 0.001$) in average scores were obtained among samples kept hot for different periods of time (1, 2 and 3 hr) and at different temperatures (45, 60 and 75°C) for one hr only, though, did not cause any difference between the samples held hot at the two lowest temperatures. With the peas held at 75°C, all properties, except the odor attributes, had deteriorated more than the samples stored at 45 and 60°C. Hot-holding for two hr led to a greater temperature effect. After three hr there were significant differences between the temperatures for all sensory properties, again with the exception of the odor attributes for samples at 45 and 60°C. The authors concluded that green peas are sensitive and deteriorate quickly, therefore storage time should be shortened as much as possible to maintain good quality.

Blaker and Ramsey (1961) studied the type of hot-holding equipment used at that time in foodservice establishments and recorded the visible changes in the food which would indicate a decrease in quality. These were the types of steam tables used: a) table-service dining room--wet steam table; b) college pay cafeteria--wet steam table; c) commercial cafeteria--wet steam table; and d) industrial cafeteria--electric dry table. One of the foods used was mashed potatoes, which became waxy-looking at temperatures above 150°F after 20 min hot-holding. Increasing temperatures and/or long holding periods on wet steam tables caused potatoes to become stiff, crusted and discolored from the top. With electric dry tables, the trend was reversed, with a more severe crusting and discoloration starting at the bottom of the pan.

Blaker and Ramsey (1961) also studied green vegetables cooked in an open kettle, which became slightly discolored after 30 min on the steam table (with no intermediate holding). The green vegetables were discolored noticeably in 15 min if they were held in a heat-holding cabinet for as little as 15 min before being transferred to a steam table. The amount of discoloration appeared to be affected more by holding time and temperature than temperature alone and vegetables held over 45 min at high temperature discolored the most.

No signs of drying were noted with yellow vegetables after one hr on the steam table above 150°F. Baked sweet potatoes became soggy and shriveled after one hr at 160°F, either on the steam table or in a heat-holding cabinet. All vegetables tended to deteriorate with extended holding, becoming overcooked, soft and mushy.

A laboratory study also was conducted by Blaker and Ramsey (1961) since many of the food items examined previously were not on the steam table long enough to determine adequately the effect of holding time and temperature on quality. Seven food items were prepared daily and placed on a steam table for a 2.5 hr holding period. A different green vegetable was chosen each day. Peas, green beans, asparagus and broccoli were cooked until tender but still slightly crisp and were held on the steam table for 2.5 hr periods. Visible changes were recorded by comparing the samples to a control every 15 min. All four of the vegetables became overcooked at 30 min holding. Some fading in color of peas and green beans occurred after 30 min holding; for asparagus this was noticeable after 45 min and for broccoli after 60 min. A distinct color change was noted at 50 min holding for the peas, 60 min holding for the green beans and 75 min holding for both asparagus and broccoli.

Mashed potatoes were prepared daily and held on the steam table in the same manner as green vegetables. Quality of mashed potatoes prepared from potato flakes and hot, seasoned milk was found to deteriorate rapidly and the authors recommended that the holding period for mashed potatoes not exceed 30 min (Blaker and Ramsey, 1961).

Meat and fish. Karlström and Jonsson (1977) studied cod in addition to the white potatoes previously mentioned. Frozen squares of cod fillets were cooked in aluminum foil under closed lids in a convection oven at 180°C to an average internal temperature of 65°C. The hot-holding conditions were the same as for the potatoes. With the cod, the hot-holding time had a statistically significant, but in practice unimportant effect; temperature did not affect the flavor.

Fillets of herring were salted, breaded and fried to an average center temperature of 65°C before hot-holding. The fillets were kept in aluminum pans, loosely covered with thin aluminum foil, for two hr at 75°C and for four hr at 60, 75 and 90°C. A newly fried sample also was studied. A decrease in the sensory scores for herring was found to be significant after four hr.

Hamburgers were fried to two different internal temperatures (70 and 90°C) and then hot-held for three hr at 75°C in aluminum foil packages under closed lids. Taste panel evaluations indicated the deterioration in sensory quality (flavor and juiciness) was generally significant after hot-holding ($p \leq 0.001$).

Boyle and Funk (1970) compared the effects of selected times and temperatures during holding on the quality characteristics of roast beef served immediately after cooking and after holding by three methods. Quality characteristics were determined by sensory evaluation and objective measurements. Losses as a result of holding also were calculated. Roasts were held: a) unsliced; b) sliced over dry heat for 90 min; and c) refrigerated for approximately 24 hr before slicing and reheating. Thermostats on the food warmers used for the 90 min holding periods were adjusted to control internal temperature of the meat. For holding, all pans containing the sliced or unsliced meats were covered with aluminum foil before other pans of the same size were inverted over them to serve as covers. After removal from the oven, roasts stood undisturbed at room temperature for 30 min, with continuous recording of the time-temperature relationship to determine the maximum temperature rise of the interior of the roast. The roasts that were held unsliced were transferred to weighed counter pans at the end of the 30 min standing period and were held for 90 min over dry heat in a food warmer with a temperature of 106 ± 10°C on the floor of the warmer. Internal temperature of the meat rose from an average of 55.5°C to 58°C during holding. Roasts that were held after slicing were placed in weighed half-counter pans and held for 90 min. A temperature of 137 ± 5°C was maintained on the floor of the warmer. The initial internal temperature of the sliced meat was 48.5°C and increased to 59°C during holding.

During the third holding, the cooked roasts were transferred to weighed counter pans and refrigerated at 5°C for about 24 hr. Roasts were then sliced and reheated to an internal temperature of 60°C in a 149 ± 1°C oven. Samples were then served as soon as possible after cooking, holding or reheating, using hot plates to keep the samples warm. Meat samples were evaluated for aroma, color of lean, flavor of lean, flavor of fat, juiciness and tenderness. The scoring method and chew count on which tenderness evaluations were based were those of Funk et al. (1966).

Tenderness of the roasts were measured objectively with the Kramer shear press. The pounds of force required to shear the meat sample were recorded on a time force curve by an electronic indicator and the maximum force per gram was calculated. Press fluid was determined by the method of Funk et al. (1966) using 7.2-11.6 g samples.

ANOV of subjective data showed roasts served immediately or held unsliced scored significantly higher ($p \leq 0.01$) for aroma, color of lean, flavor of fat, juiciness and tenderness than roasts held sliced or refrigerated and reheated. Those served immediately and those held unsliced scored significantly higher in flavor of lean ($p \leq 0.01$) and juiciness than roasts refrigerated and reheated.

No significant differences attributable to treatment or to animal were found for shear-press values. Roasts served immediately had the lowest mean shear-press reading of 16.37 ± 2.87 lb of force per gram, while those held sliced required more pounds of force per gram, 19.03 ± 2.13 to shear the sample. The roasts held unsliced and roasts refrigerated and reheated had similar values of 17.18 ± 1.69 and 17.23 ± 1.69 lb of force per gram respectively. A significant negative correlation coefficient ($r = -0.41$) was obtained between tenderness scores and shear-press values. As tenderness scores increased, less force was required to shear the meat.

According to press fluid yields, the differences in percentage of press fluid due to treatment were highly significant. The roasts that were refrigerated and reheated had the lowest percentage of press fluid yield, 51.24 ± 4.00, and the roasts served immediately, held unsliced, and held sliced had press fluid percentages of 58.55 ± 1.92, 57.45 ± 2.71 and 54.32 ± 2.80 respectively. Roasts served immediately and roasts held unsliced were significantly more juicy ($p \leq 0.01$) than those refrigerated and reheated. Significant differences ($p \leq 0.05$) were also noted between the juiciness of roasts served immediately and roasts held sliced. The sliced roasts subjected to heat for a longer period had the lower juiciness scores.

In summary, scores of panelists indicated that the roasts served immediately and those held unsliced were similar in terms of the quality characteristics of aroma, color of the lean, flavor of the lean, flavor of the fat, juiciness and tenderness. All of the scores for the roasts held unsliced and those served immediately were higher than those from roasts held sliced and roasts refrigerated and reheated. The percentages of press fluid followed the same trend, but shear-press values of tenderness indicated no significant differences among treatments.

Boyle and Funk (1970) recommended that roasts be served immediately after cooking to ensure the highest quality, and if refrigeration is necessary it is best not to slice the roast. Holding and reheating caused a decrease in the scores for flavor of lean and fat, so it was recommended that those practices be avoided.

Blaker and Ramsey (1961) also used meat during their testing. Sliced meats with no gravy appeared dehydrated above 160°F after 15 min and portioned meats without gravy showed signs of drying after 30 to 45 min, particularly if the meat was held initially in a warm oven before being transferred to the steam table. The drying was less apparent if the meat was held in a heat-holding cabinet.

In the laboratory study that was conducted by Blaker and Ramsey (1961) various food items were held on a steam table for a 2.5 hr holding period. Roast beef and baked ham held unsliced had a small amount of surface drying after 2.5 hr holding during which both were above 140°F for 1.5 hr, with the beef remaining above this temperature for two hr. Slices of roast beef and ham served "au jus" showed evidence of surface drying after 15 min, and sliced rare roast beef became well done during this time. Sliced beef covered with beef gravy held for 2.5 hr had surface drying and scum formation.

Funk et al. (1966) studied a delayed service cookery of loin cuts of beef. This method involved browning the cut of meat at a high temperature for a period of time, dependent on the size of the cut, and transferring it to a temperature controlled cabinet at 60°C until needed. Holding periods, ranging from 3 to 48 hr, reportedly resulted in safe, high quality roasts. The purpose of their study was to compare heat penetration rates in roasts cooked by the delayed service method and by the conventional dry heat method. Quality was evaluated by both sensory and physical tests. The cooked meat was evaluated as soon as possible after slicing, using hot plates to keep the samples warm. Samples were scored for aroma, color of lean, flavor of lean, flavor of fat, juiciness of lean, tenderness and chew count.

Results of the sensory evaluation were that the surfaces of the delayed service roasts were browner and drier in appearance, especially those held for 18 hr, when compared with conventionally cooked roasts. Differences in aroma scores were not significant and neither were differences in flavor of the lean meat. All roasts were scored equally good in flavor. Differences in color of lean scores for delayed service and conventionally cooked roasts were highly significant ($p \leq 0.01$). Conventionally cooked roasts scored the highest for color of lean, indicating it was closest to being of excellent quality, with both light brown and pink shading. Slices from the delayed service roasts had little pink color and consequently received the lowest score. ANOV was calculated on average flavor scores of fat which showed differences between delayed service roasts with an 18 hr holding period and those with a six hr holding period or conventionally cooked roasts, $p \leq 0.05$. The flavor of the fat from the delayed-service roast held 18 hr was scored the lowest and the judges described it as a burnt flavor. The difference between sensory juiciness scores of delayed service roasts with an 18 hr holding period and conventionally cooked roasts was highly significant, $p \leq 0.01$, with conventionally cooked roasts being juicier than 18 hr delayed service roasts. Juiciness scores indicated that conventionally cooked roasts were significantly juicier ($p \leq 0.01$) than delayed service roasts held 18 hr. The average tenderness scores, which indicated very tender meat, of the conventionally cooked roasts and the delayed service roasts held 18 hr, were significantly higher ($p \leq 0.05$) than the average score for the delayed service roasts held six hr, which indicated tender meat.

Press fluid was measured with the Carver press by simultaneously subjecting duplicate 8-10 g samples of meat to 15,000 lb pressure/sq in for 10 min. The press fluid was calculated as the difference between the initial and the pressed weight of the sample. The two values were averaged. No significant differences in the percentage of press fluid attributable to method of cooking were found. The correlation coefficient between juiciness scores and press fluid values was not found to be significant.

When tenderness was measured using the Warner-Bratzler shear and the Kramer shear-press, no significant differences attributable to cooking method were found for values from either instrument. The correlation coefficient between tenderness scores and objective measurements of tenderness by either instrument were not significant. Since conventionally cooked roasts scored higher in all palatability factors except aroma, the researchers recommended that conventional roasting methods rather than delayed service cookery be used.

Gaines et al. (1966) conducted a study to determine the effect of two delayed service methods on top round beef roasts: a) browning and then holding for 24 hr at 140°F or for 16 hours at 158°F; and b) roasting at 300°F to an internal temperature of 140°F after browning. The roasts were scored for exterior color; the samples for interior color, juiciness, tenderness, texture and flavor on a 5-point acceptability scale by a taste panel.

Tenderness was found to be influenced by the cooking method according to the Warner-Bratzler shear measurements. The roasts cooked at 300°F required significantly less shearing force than did roasts prepared by either of the delayed service methods.

During sensory evaluation of the samples the roasts cooked at 300°F were compared with roasts held 24 hr at 140°F and 16 hr at 158°F. The taste panel rated the 300°F roasts more palatable ($p \leq 0.01$) than the roasts prepared by the delayed service methods. The 300°F roasts scored higher than the delayed service roasts in acceptability of exterior color, interior color, tenderness and flavor. Differences in the juiciness and texture scores were smaller. In the case of the 16-hr held roast, though, the mean juiciness score was higher than that of the 300°F roasts. Overall, the 24-hr and 16-hr top round roasts were considered slightly too rare by a majority of the taste panelists. As mentioned earlier the 300°F roasts were significantly more tender than the 24-hr or the 16-hr held roasts as measured by the taste panelists and the Warner-Bratzler shear. A possible explanation for the low tenderness scores of the 24- and 16-hr held roasts was the fact that they only reached low internal temperatures of 121.6 and 131°F. Gaines et al. (1966) suggested further work was needed cooking to an internal temperature greater than 131°F to determine if this would produce a more tender, palatable product.

Entrees. Blaker and Ramsey (1961) in their study of different types of hot-holding equipment, investigated the effects of them on a variety of foods that would be served in an institutional-type setting. Liquid food, such as soup, or a food covered with a liquid, like a sauce or gravy, did not appear to undergo any change in quality between 150 to 160°F. Products made without milk or cream seemed not to deteriorate at higher temperatures. In the laboratory study of Blaker and Ramsey (1961) in which seven food items were prepared each day and held on a steam table for 2.5 hr, food such as cream soup and two other entrees were prepared and visible changes in quality noted. Both escalloped potatoes with ham and creamed ham were held for 1.25 hr without any visible change in quality. After 1.25 hr, both items became creamier in color and developed surface drying and scum formation. After 2.5 hr curdling was noted.

Four cream soup samples were checked against a control every 15 min and no visible changes in quality were noted during the first hour of holding. After 60 min, however, all cream soups became darker, but there was no evidence of curdling.

Blaker and Ramsey (1961) concluded that the wet steam table was more efficient in increasing or maintaining temperatures with minimum quality damage to the food product than the dry "steam" table. They recommended the development of adequate and accurate temperature controls for steam tables, since they found the quality of food held on the steam table appeared to be affected by a time-temperature relationship.

Spaghetti and meat sauce. Klein et al. (1984) reviewed studies conducted by the NC-120 committee involving spaghetti and meat sauce. These studies helped identify problem areas in reproducibly measuring specific qualities of a menu item using sensory evaluation by trained taste panels. The same formulation was used in all studies and the preparation techniques, either home or foodservice, were standardized as much as possible and a common scoring procedure was used for evaluations by trained panelists.

Either the IUTM or the Allo-Kramer Shear Press was used to measure spaghetti texture, which was then compared to sensory scores for firmness. Home and foodservice preparation, holding, storing and reheating were areas investigated. The quantity of food prepared was adjusted appropriately for the method used.

At Iowa State University, characteristics of spaghetti held 45, 90 and 180 min in a simulated hot-holding system at 74°C were evaluated fresh and at each holding time. Sensory scores indicated that the spaghetti became softer, less chewy and had more clumping the longer it was held. Moist appearance decreased with length of holding and dryness (mouthfeel) increased. Overall, no major changes in intensity of spice or beef flavors, off-flavors and blending of flavor in the spaghetti and meat sauce were noted during holding.

The study by the group in Illinois involved sensory evaluation of freshly prepared and hot-held spaghetti. The spaghetti was hot-held in a conventional foodservice system for 90 min at 65°C. Scores indicated the spaghetti became softer, less chewy, drier (mouthfeel), less moist (appearance), and more clumped on holding. The intensity of spice flavor decreased and off-flavor increased after 90 min holding.

The effect of freeze-thaw cycles on spaghetti quality characteristics was investigated at Kansas State University. Sensory analysis was done on freshly prepared and frozen spaghetti using a cook/freeze system with 5 wk freezer storage and 1, 3 and 5 evenly spaced freeze-thaw cycles compared with 5 immediate freeze-thaws and then stored. Spaghetti clumping, dryness (mouthfeel) and off-flavor increased with all treatments compared to the fresh. A progressive softening of the spaghetti was noted after 1, 3 and 5 freeze-thaw cycles and the 5 immediate freeze-thaws when compared to the fresh sample.

Freshly made, and reheated spaghetti with and without incorporated soy were prepared by household techniques and investigated by sensory analysis at Michigan State University. Clumping and dryness increased for all treatments, with the greatest increase seen by microwave reheating.

Intensity of off-flavor increased for all treatments but intensity of spice flavor decreased with reheating. Overall, moistness (appearance) decreased, with the greatest decreases with microwave reheating. Firmness decreased slightly for most treatments, the greatest decrease was with 20% soy, reheated on the stove. Spaghetti chewiness decreased except with 20% soy, reheated by the microwave.

Research at Ohio State University compared sensory quality of fresh, and reheated spaghetti and meat sauce using institutional convection and microwave ovens after holding for 1 hr chilled, 24 hr chilled, 24 hr frozen and 24 hr frozen followed by 24 hr chilled. The various holding treatments caused differences in moistness, clumping, firmness and chewiness of pasta and in overall ratings for quality and liking. Samples held 1 or 24 hr chilled had better scores than those held 24 hr frozen or 24 hr frozen plus 24 hr chilled. Spaghetti heated in the microwave compared to the convection oven had greater fat separation, clumping, greasiness, firmness, and chewiness. This decreased food quality was generally associated with heating frozen products or products held 24 hr frozen, then 24 hr chilled. Therefore, according to the researchers, if food is to be held and reheated, the best option appears to be chilled storage and reheating in the microwave oven.

Another study conducted at Iowa State University concentrated on the effects of hot-holding time on spaghetti firmness. Christensen (1981) determined the effects of 1.25, 2.5 and 3.75 hr hot-holding on spaghetti firmness by using the multiblade shear cell attached to the IUTM.

Changes in firmness attributable to treatment effect were not significant because of marked variance in firmness scores among samples within each replication. When firmness scores were changed into proportional scores, ANOV revealed a highly significant difference attributable to treatment effect. The mean proportional losses of spaghetti firmness were 49.4, 54.1 and 58.9 percent of the original firmness scores for 1.25, 2.5 and 3.75 hr of hot-holding respectively. During the 1.25 hr interval of hot-holding most of the firmness was lost, with relatively minor decreases in firmness occurring as hot-holding time increased.

Thiamin retention and hot-holding

One important factor that must be considered in today's society is the effect of home and foodservice practices on the nutritional quality of food. The major loss of vitamins and minerals in foods often occurs during final preparation in the home or institution prior to eating (Anonymous, 1974). The nutritional quality of food served by the food-service industry is increasingly more important as more meals are being consumed away from home by the average American (Anonymous, 1978). Within the foodservice industry are 30 or more distinct sectors, such as full-service restaurants, fast food outlets, school foodservice and health-care foodservice, each of which is concerned with the feeding of different segments of the population. Naturally, the methods of food handling used by these various kinds of establishments, the menus, the type of equipment, quality and quantity of food purchased and professional skill of personnel employed will vary greatly (Livingston et al., 1973). Although a menu has been planned for optimal nutrition, many nutrient losses can take place in the individual unit operations which make up the foodservice sequence: purchasing, storage, preparation, cooking, holding and serving. Critical control points regarding nutrient retention would probably be associated with purchasing, preparation, cooking and holding. The word "probably" is used because the data base available for decision-making in this area is limited (Livingston and Chang, 1979). The effect of hot-holding on the thiamin content of food will be covered in this section.

Factors involved in thiamin loss. Temperature, pH and time of heating, processing or storage are the most important factors contributing to the loss of thiamin in food products (Dwivedi and Arnold, 1973). Thiamin is readily degraded in neutral and alkaline solutions even at low temperatures (Borenstein, 1975). The specific conditions leading to thiamin destruction in food have been evaluated. Feaster et al. (1947) subjected buffered thiamin solutions to heat at temperatures in the range of 180 to 250°F. They concluded that: a) an increase in pH value from 3.5 to 7 caused a progressive decrease in thiamin retention; b) with a fixed pH value and heating time, thiamin retention decreased with increasing temperature; and c) at a fixed pH value and temperature, thiamin losses were approximately proportional to time of exposure. Another study done by Feliciotti and Esselen (1957) showed that the rate of thiamin destruction in phosphate-buffered solutions in the pH range of 4.5 to 7.0 increased with increasing pH. The most pronounced change in the reaction rate occurred between pH 6.0 and 6.5. According to Rice and Beuk (1945), at temperatures above 77°C, the rate of loss of thiamin was constant at any given temperature and was proportional to the temperature. Below 77°C, the rate of loss decreased during the first 16 to 24 hr, and then apparently remained constant. In this lower temperature range, the rates of loss were proportional to the temperature.

Thiamin in foods is more resistant to thermal breakdown than is the pure vitamin in aqueous or buffered solutions. The thermal destruction of thiamin in foods may be dependent on the interrelationship of pH and the relative proportions of the free and combined forms of the vitamin. At a given pH level the rate of destruction of thiamin increased with increasing content of the combined form (Feliciotti and Esselen, 1957). Additional factors besides pH and heat which contribute to thiamin degradation are oxidation-reduction systems, inorganic bases, enzymes, metal complexes and radiation. Model systems generally have been employed to determine the nature of thiamin degradation reactions and products. Food systems have received limited use in thiamin degradation studies because of their complexity. Lack of quantitative information on degradation products has limited the understanding of the mechanisms of thiamin breakdown. The nature of compounds produced in model systems suggests that thiamin degradation may contribute to flavor of heated food systems.

Thiamin destruction in food systems. Studies have been done using a variety of food systems to determine the relationship between hot-holding and the destruction of thiamin. Kahn and Livingston (1970) compared thiamin retentions for beef stew, chicken a la king, shrimp newburg and peas in cream sauce freshly prepared and held on a steam table at 180°F for 1, 2 and 3 hr with retentions measured when the foods were frozen and reheated by boiling water immersion, infrared heating or microwave heating. Mean thiamin retentions for the four products were 93.5% in the frozen-microwave heated products; 90% in the frozen-infrared heated products; and 78%, 74%, and 67% in the fresh hot products after 1, 2 and 3 hr, respectively. An exception was found with the peas in cream sauce reheated by immersion in boiling water, as their retention was the same after reheating as the fresh product held for one hour (Kahn and Livingston, 1970).

Based on the mean for the four products studied, a difference of as much as 0.26 µg of thiamin per gram of food could occur between fresh food held hot for three hr and the microwave-heated frozen food. In an institution where two hot meals per day are served, assuming a total intake of 20 oz of entrees and vegetables per day, the thiamin difference is equivalent to as much as 18.4% of the daily recommended allowance for certain age groups (Kahn and Livingston, 1970).

In the study by Ang et al. (1975) a general pattern among the six products studied, which were mashed potatoes, pot roast with gravy, peas with onions, beans and franks, diced carrots and frozen fish portions, indicated that the freshly prepared products retained the greatest amount of thiamin followed by the product after hot-holding for 30 min. An inverse relationship was found to exist between the holding time and the thiamin content. The mean retention in all six products was 82.6% after three hr of hot-holding (Ang et al., 1975). Frozen fish fillets handled conventionally retained 91% of their thiamin if held 1.5 hr. This retention decreased to 77% if held three hr. Conventionally prepared mashed potatoes' thiamin retention varied from 97% for a half-hour holding to 82% for three hr holding. Retention in carrots as well as peas and onions showed similar trends although percentages of thiamin retention were slightly higher.

Lachance et al. (1973) studied the thiamin retention of commercial chicken pot pies which were frozen, and either reheated in a convection oven, infrared oven or conventional electric oven to an internal temperature of 180°F. After heating they were held uncovered at 180°F for 30 min to simulate steam table operation. The mean loss of thiamin averaged 18% compared to a 7% loss in the covered samples during heat conditioning. This demonstrates that pot pies do lose thiamin on the steam table and also indicates that thiamin oxidizes on exposure to air, especially at higher temperatures.

Boyle and Funk (1972) compared the thiamin content of beef roasts held over dry heat for 90 min before and after slicing, or refrigerated for 24 hr, sliced and reheated to roasts sliced and served immediately. The roasts were cooked to an internal temperature of 54°C and allowed to stand undisturbed for 30 min after removal from the oven; during this time the internal temperature rose to 60°C. During the 90 min holding period over dry heat, maximum internal temperatures recorded for the roasts held unsliced and sliced were 58 and 59°C, respectively, while reheated slices reached a maximum temperature of 60°C during the reheating period. For roasts a) held unsliced; b) held sliced; c) refrigerated, sliced and reheated; and d) sliced and served immediately, the thiamin retentions were 79.2, 76.5, 67.8 and 78.8%, respectively.

Munsell et al. (1949) studied vitamin content and retention in cabbage prepared as coleslaw and cooked by large-scale methods and held. Holding of the boiled cabbage on the stove for 75 min resulted in an additional significant loss of thiamin from the cooked state of 6%, resulting in 35% retention.

Information on the destructive effects of restaurant cooking was studied by Nagel and Harris (1943). In this study, nine vegetables were selected and thiamin determination was done before cooking, after cooking and after three hr on the steam table. The total cooking and steam table losses averaged 70% for thiamin. According to their results, about 20% of the initial thiamin was destroyed by cooking, 25% more was lost in the discarded cooking water and an additional 25% was lost on the steam table.

Results were averaged for all the vegetables and marked differences in losses of thiamin in the various vegetables were found.

Ang et al. (1978) determined thiamin retentions of frozen beef-soy patties, raw or char-broiled, and frozen, fried, breaded chicken parts heated by various methods and held. Thiamin retention was lowest in chicken parts reheated by convection methods and held hot for three hr (74%). Good thiamin retention occurred in raw patties cooked by convection heat and held hot up to 1.5 hr. The lowest thiamin retentions were found in raw, convection-cooked patties held for three hr and infrared-heated patties held for one-half hour.

In a foodservice operation at Iowa State University, apparent thiamin retention of spaghetti and meat sauce was 74% following 90 min holding at 70°C/158°F and 83% after holding 3.75 hr, wet weight basis. Differences can be attributed to moisture loss during holding since no adjustments were made (Brown and Love, 1982). A similar study at the University of Illinois showed that apparent thiamin retention after 90 min holding at 65°C/150°F was 87%, wet weight basis, or 83%, dry weight basis (Klein et al., 1982).

The effect of steam table holding on the thiamin content of potatoes prepared different ways was investigated by Streightoff et al. (1946a). Potatoes steamed, boiled just until done or boiled two hr showed statistically significant losses of thiamin. When these products were held on the steam table one hr, the losses were higher than after cooking alone. The thiamin losses were 12, 21 and 36 percent, respectively. Significant losses from holding alone, calculated by difference are: for steamed potatoes, 8% thiamin; for potatoes boiled done, 4%; and for potatoes baked done, baked done and held two hr and baked done and held four hr significant losses, respectively, of 7, 11 and 20 percent thiamin were reported. In contrast, Gleim et al. (1946a) found holding steamed potatoes in the steamer with the steam turned off for 30 min resulted in no further losses of thiamin for the holding period.

Other research studies have been done which also report no losses of thiamin or very minor ones due to the hot-holding of foods. Numerous studies have been done with vegetables, and the effect of hot-holding on their thiamin content.

Fenton et al. (1946) found no significant thiamin destruction in cabbage which was held in an institution type warmer at 60°C for 90 min. In another study by Wood et al. (1946) cooked cabbage was held warm by three methods: a steam counter, thermotainer and a warmer, for a total of 120 min. They found no statistically significant loss of thiamin during holding. Likewise, Sutherland et al. (1947) found cabbage cooked by an institutional method and held 1.5 hr over steam was not lower in thiamin than the freshly cooked household product. Spinach cooked by an institutional method and held over steam lost none of its thiamin and was equal to the freshly cooked household product in thiamin content. Results of a study by Streightoff et al. (1949b) in which boiled and drained spinach was held in a stainless steel tray over boiling water for an hour, indicated no significant effect on thiamin retention. A study by Fenton et al. (1943) found no appreciable loss of thiamin in steam-cooked dehydrated beets, cabbage and rutabagas after holding for one hr in an institution-size warming oven, during which all the water was absorbed by the vegetables.

Gleim et al. (1946b) held carrots in an aluminum stock pot on the gas range for 1.5 and 3 hr at approximately 65°C. This resulted in an increase in percent retention of thiamin in the carrots themselves and a decrease in the cooking water. No destruction occurred during holding. Streightoff et al. (1946b) held boiled or steamed carrot slices in one-gal stainless steel pans on a steam table for one hr, which resulted in little or no loss of the B-vitamins. In another study by Streightoff et al. (1949a), boiled corn was held over boiling water for one hr which resulted in no significant loss of thiamin. Jones et al. (1944) found that drained broccoli cooked in a steam-jacketed kettle and held in an electrically heated service counter had little loss of thiamin even at the end of two hr. The large-scale preparation of eight canned vegetables was studied by Hinman et al. (1944). When the vegetables were held for 1.5 hr and all the liquid was retained, retention of thiamin was practically complete both during long boiling and holding over steam. They concluded that when some liquid is discarded, which happens when a slotted spoon is used, the loss of all the vitamins is considerable and is directly related to their concentrations in the boiled liquid and to the proportion of liquid discarded.

Westerman (1948) found that sliced roast pork held for 30 min over rapidly boiling water retained 91% of the thiamin. Erickson and Boyden (1947) reheated turkey and held it on a steam table and found this had little destructive effect on thiamin. Khan et al. (1982) found that thiamin retention of Italian spaghetti on a dry, fat-free basis, was 99.2 ± 13.9 for the hot-held product held for 90 min at approximately 66°C on a preheated steam table. No significant thiamin losses occurred during holding of the fresh product based on the data.

Lee et al. (1981) evaluated for thiamin content oven-baked chicken breast halves when prepared and served by a cafeteria-style foodservice system. After preparation, they were held on a steam table for 90 min at approximately 66°C. The researchers concluded that significant thiamin losses occur during cooking rather than during hot-holding.

MATERIALS AND METHODS

This study was conducted in the Foods and Nutrition research and sensory analysis laboratories and in the quantity foods laboratory in the Dietetics, Restaurant and Institutional Management Department, Kansas State University. Experimental data were collected in May-June, 1983. Conditions in household and foodservice systems were simulated.

Preparation of spaghetti and meat sauce

The spaghetti and meat sauce formula and procedures used in this study had been selected by the NC-120 regional research team for research emphasis.

Formula. A standardized formula developed by the Institution Management Department at Iowa State University was adapted for use in the study (Boyd et al., 1971). The formulas and brands for the household and foodservice quantities are given in the Appendix, Table A-1.

All ingredients were purchased in complete lots. The seasonings, spaghetti noodles, oil and tomato sauce and paste were stored at room temperature. The ground beef was purchased fresh, frozen and held at -17°C (1°F) until defrosted.

Production. Two separate batches of spaghetti and meat sauce were prepared each day of the study. The average preparation time was two hr and 15 min for each quantity, household or foodservice. The complete procedure is included in the Appendix, Table A-2. Large and small equipment used is listed in the Appendix, Tables A-3 and A-4. The electric trunnion kettle was used in addition to the five-gal steam-jacketed kettle when the design required two foodservice preparations the same day. Since the usual preparation procedure for the spaghetti and meat sauce resulted in temperatures above 165°F before the final heating, the procedure was reversed for the foodservice method heated to 165°F. The sauce was held at room temperature while the spaghetti noodles were cooked. The sauce and noodles were combined in the steam-jacketed kettle for the final half-hour heating period.

The foodservice quantity was transferred to a 12 1/2 × 10 3/8 × 4 1/16 in aluminum pan, immediately covered with aluminum foil and transported to the preheated food conveyor. The household quantity was transferred to a three-qt glass casserole, covered with the lid and placed in the preheated food conveyor until all samples were removed.

Sensory analysis

Panelists. Eight experienced panelists from the Departments of Foods and Nutrition and Dietetics, Restaurant and Institutional Management were trained to do the sensory analyses of the spaghetti samples. In the training sessions, panelists became familiar with the score card and the terminology used in this study. Panelists were given samples corresponding to the extremes, or anchors, for each characteristic to be evaluated. The score card which was used is included in the Appendix, Figure A-1.

Serving and hot-holding of spaghetti and meat sauce. The spaghetti was served at four different times, immediately after preparation and again after 45 min, 75 min and 105 min hot-holding. Approximately three tablespoons of sample were removed from randomly selected areas in the container using a plastic spaghetti fork. The samples were placed in 3 1/2 in (od) heated custard cups which were covered with heated watch glasses, then placed in aluminum pans filled with 100 ml water held at approximately 67.3°C. A General Electric warming tray was used to maintain the temperature until distribution to the panelists. To minimize biases from order of service at the four time periods, each panelist received only two samples per day at randomly selected times. The schedule used for serving panelists is in the Appendix, Table A-5.

Immediately after samples were removed for sensory analysis, the samples were removed for chemical and instrumental analyses. A three tablespoon, a two cup and a 75 g sample were removed for moisture analysis, texture evaluation, and thiamin determination, respectively. Samples for moisture and texture analyses were placed in plastic Seal-a-meal™ bags and sealed until needed. The moisture samples were frozen until all replications were completed, then analyzed by the Animal Science and Industry analytical laboratory.

Temperature of the spaghetti was monitored before and after each serving period using a digital thermometer with a probe (Table 1). The surface temperature of the heated cart and the internal temperature of the oven were taken before and after each serving period (Table 2). The serving temperature of the spaghetti always was lower than the endpoint cooking temperatures of 165°F and 185°F.

After all samples were removed from the freshly prepared household quantity, the glass casserole was placed in a household-type gas oven set to maintain the appropriate temperature in the spaghetti, 165°F or 185°F, until the next serving period. The oven setting had to be adjusted periodically in order to maintain the appropriate temperature in the spaghetti. The freshly prepared foodservice quantity was held in the

Table 1—Spaghetti temperatures and overall temperature changes during serving for all treatments

	Serving			Overall changes		
	Minimum	Maximum	Mean	Minimum	Maximum	Mean
Treatment	°C	°C	°C	°C	°C	°C
HH 74°C (165°F)	56	76	68	-4.7	-17.4	-5.3
HH 85°C (185°F)	62	84	74	+4.1	-12.7	-6.4
FS 74°C (165°F)	62	69	66	-0.3	-6.4	-0.2
FS 85°C (185°F)	70	79	73	+0.2	+4.8	+2.6

Table 2—Minimum, maximum and mean temperature of hot-holding equipment

	Minimum	Maximum	Mean
Equipment	°C	°C	°C
Gas oven			
74°C (165°F)	49	79	58
85°C (185°F)	71	91	82
Food conveyor surface			
74°C (165°F)	52	110	72
85°C (185°F)	57	118	84
Roaster oven			
74°C (165°F)	49	99	74

covered well of the food conveyor until the next serving period. An electric roaster was used for the second sample when the design required two foodservice quantities to be evaluated the same day, since two food conveyors were not available. Controls were set on the cart or the roaster to maintain the temperature of the spaghetti as close to 165°F or 185°F as possible.

Determination of thiamin content

Thiamin analysis was done using 75 g spaghetti and meat sauce by the thiochrome method of analysis, AOAC method 43.024 (1980). The 75 g of 0.1 N HCl was added immediately to the sample and the sample was blended. Samples were autoclaved, incubated overnight, diluted and then filtered. The filtrate was collected and frozen at this point on some samples. The filtrate was purified and the thiamin converted to thiochrome. Fluorescence was measured using the Coleman Photofluorometer (Model 12C). Two duplicate readings were averaged for each sample. Thiamin analysis was done by a departmental research assistant. The percentage thiamin retained during holding of spaghetti was calculated, wet and dry weight basis, using the thiamin content of the freshly prepared spaghetti (0 hr holding) as 100%.

Measurement of spaghetti firmness

Preparation of samples. The two-cup sample of spaghetti and meat sauce removed from each treatment was rinsed in a strainer under a moderate stream of cold water for exactly two min to remove the sauce and particles of meat from the noodles. Preliminary testing which compared rinsed vs non-rinsed noodles and sauce for firmness using the IUTM showed that the differences were found to be relative among the samples so the least time consuming method of rinsing the noodles was used in the study. Virtually all the sauce was rinsed from the noodles during the two min time period. From the rinsed sample, two 55 g samples were weighed out on a Toledo balance, covered and held until needed.

Testing. Tests for spaghetti firmness were made using the Ottawa cell attached to the IUTM. A crosshead spead of 20 mm/min, full scale load of 20 (200 kg) and chart speed of 50 mm/min were used for testing the spaghetti samples. Testing began on each set of samples four hr and four min ± five min after the sample was originally removed from the larger quantity of spaghetti during the hot-holding period. The spaghetti sample was placed in the cell and loosely arranged with a fork. After compression of the first sample, the cell was cleaned thoroughly before the duplicate sample was compressed. This procedure was followed until all eight samples for each day were compressed. The two peak heights on the graph were measured; the first peak was designated initial rupture force and the second peak was designated maximum force.

Experimental design and analysis

A balanced incomplete block experimental design is shown in Table 3 below with regard to the quantity (foodservice or household) prepared and the temperature (165 or 185°F) of hot-holding used. Service and order of evaluation was randomized completely among panelists, as shown in the Appendix, Table A-5. The physical and chemical measurements were replicated only three times for each treatment due to time required and quantity of sample needed (Table A-5). Data were analyzed by ANOV, and

Table 3—Balanced incomplete block experimental design

Day	Treatment combination[a]
1	3,4
2	1,2
3	1,3
4	2,4
5	2,3
6	1,4

[a] 1 = Household 165°F; 2 = Foodservice 165°F; 3 = Household 185°F; 4 = Foodservice 185°F.

when significant differences were shown, least squares means were determined.

RESULTS

Sensory analysis

The ANOV for the sensory data is shown in Table 4. Treatment, either by household or foodservice procedures, was found to significantly influence firmness scores for the spaghetti. Temperature of hot-holding caused significant differences in clumping and firmness. The length of holding time resulted in significant differences in clumping, firmness, mouthfeel (which is a decrease in free fluids in the mouth) and appearance of moistness in spaghetti.

Table 4—Mean squares and F values[a] from analysis of variance of sensory properties for spaghetti and meat sauce

Source of variation	df	Clumping	Firmness	Mouthfeel	Moist appearance
Replication	1	3.17 (0.46)	0.03 (0.01)	6.00 (0.99)	16.50 (3.45)
Treatment (FS vs HH)[b]	1	1.21 (0.18)	19.47 (4.68)*	2.48 (0.41)	4.90 (1.02)
Temperature (165°F vs 185°F)	1	33.71 (4.88)*	22.03 (5.30)*	2.19 (0.36)	8.74 (1.83)
Treatment × temperature	1	0.46 (0.07)	2.27 (0.55)	5.38 (0.89)	4.65 (0.97)
Time	3	30.56 (4.43)**	98.72 (23.73)***	25.17 (4.16)**	13.42 (2.80)*
Treatment × time	3	4.16 (0.60)	3.14 (0.76)	1.58 (0.26)	4.13 (0.86)
Temperature × time	3	4.38 (0.63)	5.62 (1.35)	1.08 (0.18)	1.29 (0.27)
Treat × temp × time	3	7.62 (1.10)	1.89 (0.45)	14.25 (2.36)	4.20 (0.88)

[a] F-values in parentheses.
[b] FS = Foodservice, HH = Household preparation and holding procedures.
* Significant at the 5% level.
** Significant at the 1% level.
*** Significant at the 0.1% level.

Physical measurements

ANOV also was used for the physical measurements (Table 5). Temperature was a significant factor influencing thiamin retention and altering firmness as measured by the IUTM peak heights. The method of treatment also caused significant differences for thiamin content and for percent moisture. The length of holding time caused significant differences in spaghetti firmness as measured by the IUTM. A temperature × treatment interaction and a time × treatment interaction were found also to be significant in the IUTM measurements of spaghetti firmness.

Means for sensory, physical and chemical data for every treatment × temperature × time combination are given in Tables A-6 and A-7.

Effect of quantities and methods on sensory and physical measurements

Spaghetti held in the heated foodservice cart was considered significantly firmer by sensory analysis than the spaghetti held in a warm oven by household methods (Table 6). The thiamin retention (μg/g), dry weight basis, and percentage moisture also were significantly higher (Table 7) using the foodservice quantities and methods than with the household quantities and methods.

Effect of holding temperature

The higher holding temperature, 185°F resulted in less firm, more clumped ($p \leq 0.05$) spaghetti than the 165°F holding temperature (Table 6). IUTM assessments of firmness (Table 7) also indicated the spaghetti held at 165°F was firmer, having both a higher initial rupture force and a larger maximum force than the 185°F-held spaghetti. Thiamin retention

Table 5—Mean squares and F values[a] from analysis of variance of physical and chemical measurements for spaghetti and meat sauce

		Instron		Thiamin		
Source of variation	df	Initial rupture force (kg)	Maximum force (kg)	As is (µg/g)	Dry weight (µg/g)	% Moisture
Replication	1	0.04 (0.05)	0.21 (0.18)	0.12 (2.11)	1.94 (2.11)	0.23 (0.22)
Treatment (FS vs HH)[b]	1	0.75 (0.89)	0.96 (0.83)	0.01 (0.24)	3.52 (3.83)*	44.99 (44.27)***
Temperature (165°F vs 185°F)	1	8.13 (9.63)**	17.52 (15.07)***	0.52 (9.10)**	6.47 (7.03)*	0.15 (0.15)
Treatment × temperature	1	15.44 (18.30)***	18.82 (16.19)***	0.03 (0.44)	0.42 (0.46)	0.004 (0.00)
Time	3	32.75 (38.80)***	35.38 (30.44)***	0.75 (1.31)	0.71 (0.77)	0.60 (0.59)
Treatment × time	3	2.61 (3.10)*	2.88 (2.48)	0.12 (2.08)	1.49 (1.62)	1.05 (1.04)
Temperature × time	3	1.01 (1.20)	0.80 (0.69)	0.04 (0.72)	0.64 (0.70)	0.20 (0.20)
Treat × temp × time	3	0.59 (0.70)	1.02 (0.88)	0.09 (1.59)	1.29 (1.40)	0.08 (0.080)

[a] F-values are in parentheses.
[b] FS = Foodservice, HH = Household preparation and holding procedures.
* Significant at the 5% level.
** Significant at the 1% level.
*** Significant at the 0.1% level.

Table 6—Least squares means[a] for sensory properties of spaghetti and meat sauce

Source of variation	Moist appearance	Clumping	Mouthfeel	Firmness
Treatment				
Foodservice	8.97	10.58	7.69	7.86
				*
Household	8.42	10.31	8.09	6.76
Temperature				
165°F	9.07	11.17	7.70	7.90
		*		*
185°F	8.33	9.72	8.07	6.72

[a] Data is pooled for each source of variation; 96 observations/mean.
* Difference significant at $p \leq 0.05$ level.

Table 7—Least squares means for physical and chemical measurements of spaghetti and meat sauce

Source of variation	Instron[a]		Thiamin[b]		
	Initial rupture force (kg)	Maximum force (kg)	As is	Dry weight (μg/g)	% Moisture[b]
Treatment					
Foodservice	19.63	21.36	1.71	6.43	73.34
				*	***
Household	19.82	21.59	1.68	5.84	71.24
Temperature					
165°F	20.14	22.08	1.81	6.53	72.23
	**	***	**	*	
185°F	19.31	20.87	1.58	5.74	72.35

[a] Data is pooled for each source of variation, 48 observations/mean.
[b] Six observations/mean.
Significance indicated as follows: *, $p \leq 0.05$; **, $p \leq 0.01$; ***, $p \leq 0.001$.

(µg/g) was greater in the spaghetti held at 165°F than in 185°F-held spaghetti, as expected (Table 7).

Effect of duration of holding period

Sensory. Limitations imposed by available personnel and equipment required an experimental design which confounded the varying lengths of holding times with panelists. However, the linear trends are so evident that the duration of the holding period is a factor obviously affecting sensory quality. The spaghetti appeared drier and became less firm with increased holding time (Fig. 1, 2). The freshly prepared spaghetti was significantly firmer and moister appearing ($p \leq 0.05$) than the spaghetti held 45, 75 or 105 min (Table 8).

A reduction in free fluids in the mouth was called a dry mouthfeel. Dryness in the mouth increased in a linear fashion with hot-holding time (Fig. 3) as expected. The freshly prepared spaghetti was significantly ($p \leq 0.05$) more moist by mouthfeel and by appearance as compared to the spaghetti held 45, 75 and 105 min (Table 8). Means for dryness of mouthfeel for each method of preparation and temperature are shown in Table A-8 as the treatment by temperature interaction was significant at the $p \leq 0.08$ level. No trends for method of preparation or for temperature are shown with the varying holding times. Spaghetti held 105 min exhibited greater clumping ($p \leq 0.05$) than the freshly prepared spaghetti and the spaghetti held for 75 min (Table 8).

Physical. Firmness, as evaluated instrumentally by the IUTM, also decreased with length of holding time (Table 9). These results agreed with the sensory data on firmness (Table 8). The simple correlation

Fig. 1—Effect of hot-holding time on least squares means of sensory scores for moist appearance, pooled for all treatments and temperatures totaling 48 observations/mean.

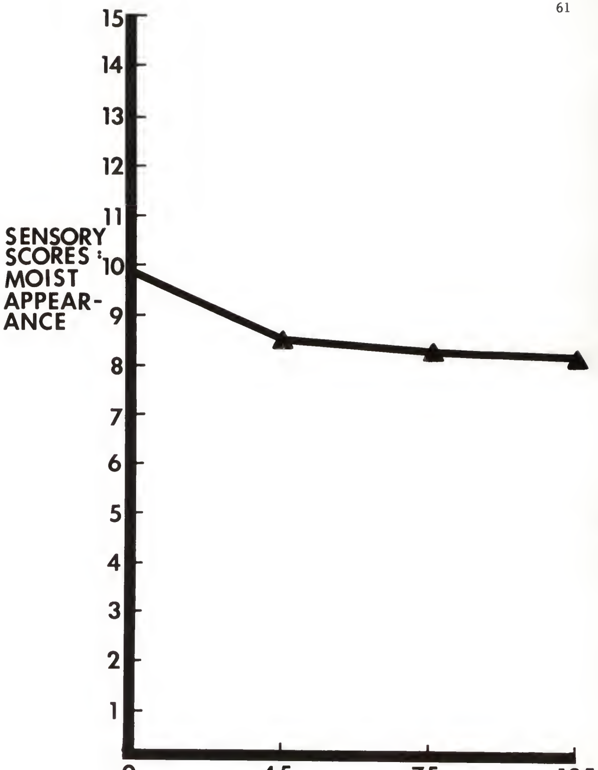
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
SENSORY SCORES: MOIST APPEARANCE
0
45
75
105
HOLDING TIME(min)

Fig. 2—Effect of hot-holding time on least squares means of sensory scores for firmness, pooled for all treatments and temperatures totaling 48 observations/mean.

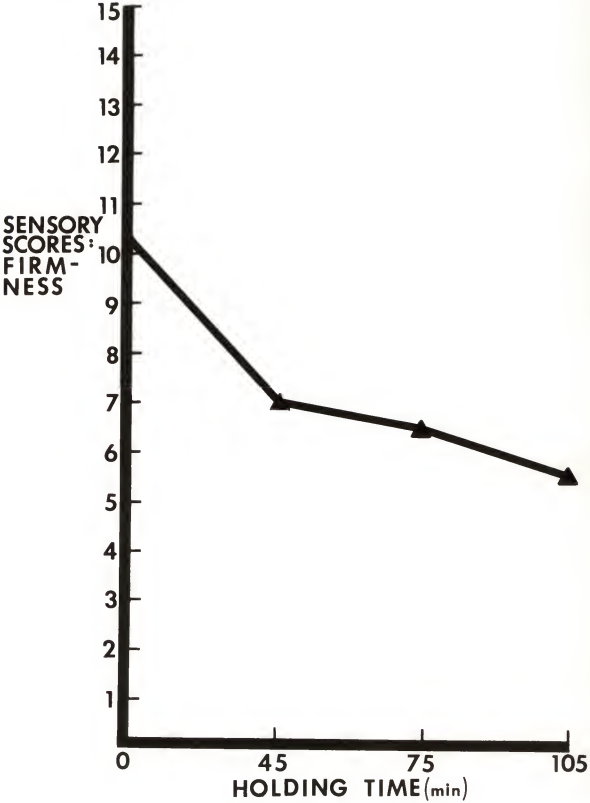
SENSORY SCORES: FIRM-NESS
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
45
75
105
HOLDING TIME(min)

Table 8—Least squares means[a] for sensory properties of spaghetti and meat sauce

Source of variation	Moist appearance	Clumping	Mouthfeel	Firmness
Holding times (min)				
0	9.80[a]	11.74[a]	6.44[a]	10.20[a]
45	8.53[b]	10.15[bc]	7.90[b]	7.01[b]
75	8.27[b]	10.83[ac]	8.64[b]	6.51[bc]
105	8.20[b]	9.10[b]	8.58[b]	5.51[c]

[a] Means in a column sharing a common superscript are not significantly different ($p \leq 0.05$); Data for household and foodservice at 165 and 185°F pooled for a total of 48 observations/mean.

Fig. 3—Effect of hot-holding time on least squares means of sensory scores for mouthfeel/dryness, pooled for all treatments and temperatures totaling 48 observations/mean.

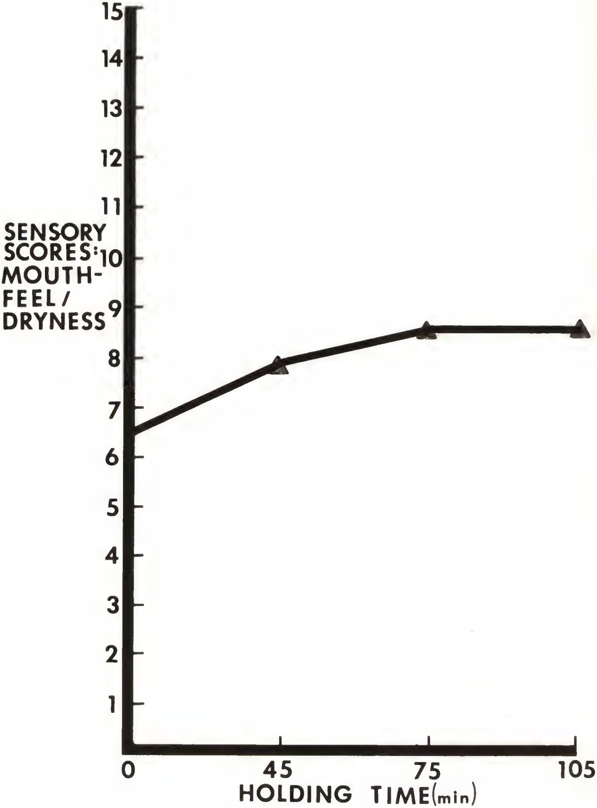
15
14
13
12
11
SENSORY SCORES: MOUTH-FEEL / DRYNESS
10
9
8
7
6
5
4
3
2
1
0
45
75
105
HOLDING TIME(min)

Table 9—Least squares means for peak heights of Instron curves

Holding time (min)	Instron: Initial rupture force (kg)[a] Household	Instron: Initial rupture force (kg)[a] Foodservice	Instron: Maximum force (kg)[b]
0	21.0[a]	21.6[a]	23.08[a]
45	19.7[bd]	19.8[b]	21.52[b]
75	19.7[bd]	19.0[cd]	21.13[b]
105	18.9[c]	18.1[e]	20.17[c]

[a] For the first two columns for initial rupture force, means with the same superscript are not significantly different ($p \leq 0.05$); 12 observations/mean.

[b] For maximum force, the data for both household and foodservice quantities are pooled, since no interaction with treatment was found. Means with the same superscript in this column are not significantly different ($p \leq 0.05$); 24 observations/mean.

coefficients, r, between sensory firmness and initial rupture force and maximum force were calculated to be .98 and .99, respectively.

For initial rupture force, a significant interaction between treatment and time was noted (Table 5). Both household and foodservice quantities of spaghetti held for 105 min were significantly the least firm ($p \leq 0.05$) and the freshly prepared spaghetti was the firmest (Table 9). With maximum force data, treatments pooled, the same trend was noted.

A treatment × temperature interaction was found to be significant for both initial rupture force and maximum force. The data indicate (Table 10) that the spaghetti held at 165°F by the household methods was significantly the most firm ($p \leq 0.05$) and the spaghetti held at 185°F by household methods significantly least firm ($p \leq 0.05$). Foodservice methods using either temperature produced spaghetti intermediate in firmness between the spaghetti held at 165°F and 185°F by household methods (Table 10).

Length of holding time had no effect on thiamin content according to the data (Table 5). No significant differences in thiamin means (μg/g) were found for length of holding for any of the treatment and temperature combinations. The calculated thiamin retentions, wet weight and dry weight basis, are shown in Tables 11 and 12.

DISCUSSION

Hot-holding of food causes destruction of thiamin as previously reported. Research done at Iowa State University by Brown and Love (1982) in a foodservice operation, showed apparent thiamin retention of spaghetti and meat sauce to be 74% after 90 min holding at 70°C and 83% after holding 3.75 hr on a wet weight basis. They attributed the differences to

Table 10—Least squares means[a] for peak heights of Instron curves

Source of variation	Initial rupture force (kg)	Maximum force (kg)
Foodservice 165°F	19.64[a]	21.52[a]
Foodservice 185°F	19.61[a]	21.20[a]
Household 165°F	20.64[b]	22.63[b]
Household 185°F	19.01[c]	20.54[c]

[a] Means in a column sharing a common superscript are not significantly different ($p \leq 0.05$); Data pooled for each treatment; 24 observations/ mean.

Table 11—Percentage retention, during holding, of thiamin, wet weight basis, for treatment and temperature combinations

	Foodservice				Household			
	165°F		185°F		165°F		185°F	
Time (min)	(μg/g)[a]	(% retention)	(μg/g)	(% retention)	(μg/g)	(% retention)	(μg/g)	(% retention)
0	2.05	100	1.63	100	1.87	100	1.59	100
45	2.17	106	1.58	97	1.60	86	1.58	99
75	1.64	80	1.58	97	1.83	79	1.60	101
105	1.54	75	1.51	93	1.77	95	1.59	100

[a] Values are least squares means, 3 observations/mean.

Table 12—Percentage retention, during holding, of thiamin, dry weight basis, for treatment and temperature combinations

Time (min)	Foodservice				Household			
	165°F		185°F		165°F		185°F	
	(μg/g)[a]	(% retention)	(μg/g)	(% retention)	(μg/g)	(% retention)	(μg/g)	(% retention)
0	7.53	100	5.98	100	6.52	100	5.62	100
45	8.12	108	5.89	99	5.50	84	5.44	97
75	6.23	83	6.02	101	6.36	98	5.55	99
105	5.82	77	5.83	98	6.17	95	5.58	99

[a] Values are least squares means, 3 observations/mean.

moisture loss during holding since no adjustments were made. A similar study at the University of Illinois showed apparent thiamin retention after 90 min holding at 65°C was 87%, wet weight basis, or 83%, dry weight basis (Klein et al., 1982). In the present study, foodservice and household quantities held for 105 min at either 165°F or 185°F had similar retention rates. For example, spaghetti held by foodservice methods at 165°F retained 75% thiamin, and spaghetti held by foodservice methods at 185°F, 93%, wet weight basis. Household quantities of spaghetti held at 165°F had 95% retention and at 185°F, 100% retention was found, wet weight basis. No significant differences in thiamin means (µg/g) were noted with any treatment (household or foodservice) × temperature (165°F or 185°F) combinations for any holding times. Khan et al. (1982) found percentage thiamin retention of spaghetti, dry, fat-free basis, to be 99.2 ± 13.9 for the product held 90 min at approximately 66°C on a preheated steam table. Percentage thiamin retention during the holding periods, calculated on a dry weight basis, also indicated high percentage retention values for some treatment × temperature combinations (Table 12).

Those percentage retention calculations initially appear to be illogical, with the percentage retentions being lower for the spaghetti held at 165°F than for the spaghetti held at 185°F, but by looking at the individual means (µg/g) for each treatment × temperature combination (Tables 11 and 12), furhter insight is possible. More thiamin was destroyed when the spaghetti was cooked to 185°F than when cooked to 165°F, therefore, less remained at the start of the actual hot-holding time to be further destroyed during the holding period. With the spaghetti cooked to 165°F, less was lost during the initial cooking of the spaghetti, but more during hot-holding, resulting in smaller percentage retentions during the holding period than for the spaghetti cooked and held at 185°F. Cooking and hot-holding both influence thiamin retention (μg/g) in spaghetti. Both holding temperatures brought the thiamin content (μg/g) down to approximately the same level in the spaghetti after the longest holding period, but this did not occur at the same rate, therefore the endpoint cooking temperature and holding temperature chosen are critical. A lower endpoint temperature and holding temperature such as 165°F would be advisable to use since more thiamin is present initially after cooking and at the various holding periods until 105 min elapsed. After 105 min, thiamin contents (μg/g) of the samples held at 165°F and 185°F were approximately the same. Livingston and Chang (1979) pointed out that critical control points as far as nutrient retention was concerned would be with purchasing, preparation, cooking and holding. Nagel and Harris (1943) determined thiamin content of nine vegetables before cooking, after cooking and after three hours on the steam table. Their results indicated 20% of the initial thiamin was destroyed by cooking, 25% was lost in discarded cooking water, and an additional 25% on the steam table. These studies also support the fact that both cooking and holding are areas of concern when dealing with nutrient retention.

A progressive decrease in thiamin retention (μg/g) was not seen with increased holding time for every treatment × temperature combination as expected. One factor which may have affected the results was the varying ratio of spaghetti to meat sauce in the samples tested. It was not possible by randomized sampling to get the same amount of meat sauce and spaghetti each time, which would affect the amount of thiamin as calculated in the samples. Overall, foodservice quantities and methods showed greater retention of thiamin, dry weight basis, than household quantities and methods. This could be explained by the fact that there were greater temperature fluctuations, including higher maximum temperature, in spaghetti held by household methods than in spaghetti held by foodservice methods (Table 1). This was true in spite of the fact that the gas oven used for household procedures had less temperature variation than the foodservice equipment (Table 2). Perhaps, this can be explained by the greater surface area as well as the small mass of the household quantities compared to foodservice quantities. As a result, more thiamin was lost during holding of a smaller quantity than a larger quantity. Feaster et al. (1947) subjected buffered thiamin solutions to heat at temperatures in the range of 180 to 250°F and concluded that: a) with a fixed pH value and heating time, thiamin retention decreased with increasing temperature. When temperature alone was looked at in relation to thiamin retention, the 165°F holding temperature in this study also resulted in greater thiamin retention in the spaghetti than did the 185°F holding temperature, based on thiamin means (μg/g) pooled for both treatments.

The IUTM was used to determine changes in firmness of spaghetti associated with hot-holding. Previous research done by Christensen (1981) showed mean proportional losses of firmness of 49.4, 54.1 and 58.9 percent of the original firmness scores for 1.25, 2.5 and 3.75 hr of hot-holding respectively. Most firmness was lost during the 1.25 hr hot-holding interval. Other results from research done at Iowa State University by Brown and Love (1982) with spaghetti and meat sauce followed the same trend, the spaghetti became softer the longer it was cooked and held. Results from the present study indicated both household and foodservice quantities held for 105 min were the least firm ($p \leq 0.05$) and the freshly made spaghetti the firmest, according to initial rupture force.

Data also indicate that temperature and treatment influenced firmness, with the spaghetti held at 165°F by household methods most firm, and spaghetti held at 185°F by household methods the least firm. Foodservice methods using either temperature produced spaghetti intermediate in firmness between the spaghetti held at 165°F and 185°F by household methods. IUTM measurements of firmness (Table 4) also indicated that spaghetti held at 165°F was firmer, with a higher initial rupture force and a larger maximum force than the spaghetti held at 185°F. By looking at the treatment × temperature effects on firmness and then the temperature effects by themselves, it can be suggested that the lower temperature, 165°F, is least destructive to the firmness of small quantities of spaghetti and would be better to use, as the lower temperature would slow down one possible cause of softening, moisture migration in the spaghetti. Voisey et al. (1976) pointed out that the process of moisture migration in the spaghetti after cooking causes textural changes to occur. Sensory scores for firmness also correlated highly with the IUTM measurements, indicating a decrease in firmness with length of holding time. This trend was also evident in work done at Iowa State University by Brown and Love (1982).

Studies at Iowa State University (Brown and Love, 1982) and the University of Illinois (Klein et al., 1982) indicated spaghetti that was hot-held from 45 to 180 min became softer, less chewy, drier (mouthfeel), less moist (appearance) and more clumped as holding time increased. Results from the current study show the same trends with increasing holding time. Again, some of these effects possibly can be attributed to moisture migration through the cross section of the spaghetti during holding which would cause the spaghetti to become softer, less chewy and have greater clumping.

When treatment was examined in relation to firmness in the present study, spaghetti held in the heated foodservice cart was considered significantly firmer by sensory analysis than the spaghetti held in a warm oven. Again, the smaller household quantity held in the oven probably had more rapid heat penetration and, therefore, faster moisture migration and softening of the spaghetti than the larger foodservice quantity.

The higher holding temperature, 185°F, resulted in less firm, more clumped ($p \leq 0.05$) spaghetti than the 165°F holding temperature. This effect of a decrease in firmness with the higher holding temperature was also seen when the IUTM was used to measure the firmness of the spaghetti samples (Table 4).

Results from firmness testing indicate that if the consumer must hot-hold spaghetti and meat sauce, a low temperature and a short time are recommended, since a high temperature for a long time seems to have a detrimental effect on spaghetti firmness. Since there were fluctuations in the oven temperature during holding, the temperature did go above 185°F, causing the internal temperature of the spaghetti to also rise, contributing to increased softening. The decrease in the other characteristics of the spaghetti and meat sauce as hot-holding time increased adds support to the conclusion that hot-holding should be avoided, or if not possible, hold only for short periods of time. Even though the foodservice quantity did not show as much softening as the household quantity, perhaps because of less fluctuation in the equipment temperature, foodservice workers should still avoid hot-holding when possible. Temperature fluctuation by the foodservice equipment, and thus in that product, does occur though. Therefore, the best recommendation to those who prepare and serve spaghetti in either setting would be to avoid hot-holding as much as possible in order to present a quality product for consumption.

CONCLUSIONS

Based on the conditions of this study, one can conclude:

1) The use of 165°F for cooking and holding of spaghetti results in less thiamin loss (μg/g) initially and until held for 105 min, than did the use of the 185°F temperature. At 105 min holding, losses of thiamin were approximately the same for the two treatments.

2) The smaller household quantities and methods resulted in greater losses of thiamin than did the use of foodservice quantities and methods.

3) Sensory and instrumental firmness scores for the spaghetti were related and indicated firmness decreased with length of holding time.

4) Instrumental measurements indicated preparation by household methods and holding at 185°F resulted in the least firm spaghetti of the treatment and temperature combinations studied, and the spaghetti prepared by household methods and held at 165°F was the firmest.

5) Sensory data indicated with increased holding time, 0 to 105 min, spaghetti became more dry in appearance and mouthfeel, exhibited greater clumping and became softer.

6) Both sensory and instrumental measurements of firmness showed that the spaghetti cooked to and held at 185°F was significantly less firm than the spaghetti cooked to and held at 165°F.

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APPENDIX

Table A-1—Formulation for spaghetti and meat sauce

Ingredients	Amounts, g	
	Foodservice	Household
Spaghetti, uncooked Ravarino and Freschi	908.0	459.0
Oil Mazola	26.3[a] 39.4[b]	13.1[a] 19.7[b]
Onions, dehydrated Sexton	24.8	12.4
Beef, ground 80% lean	908.0	459.0
Oregano, leaf Safeway Crown Colony	.4	.2
Onion salt French's	2.7	1.4
Salt Good Value	30.0	15.0
Sugar Townhouse	12.5	6.3
Tomatoes, whole Hunt's	2353.0	1179.0
Tomato paste Hunt's	288.3	147.0

[a] In cooking water.
[b] Used for sautéing.

Table A-2—Procedures used to prepare spaghetti by two methods with alternate equipment

1. Break spaghetti into 12-14 cm lengths.
2. Measure water and oil into container (7 qt 4 oz porcelain pot, or steam-jacketed/trunnion kettle[a]).
3. Bring water to boil (med-hi on electric range, setting 8 on steam-jacketed kettle, 237°F on trunnion kettle).
4. Add spaghetti slowly, stirring continuously so no clumping occurs.
5. Continue to cook for 15 minutes.
6. Drain spaghetti in a colander for five minutes.
7. Turn into container to hold.
8. Sauté rehydrated onions[b] and oil for 7 minutes (225°F on electric fry pan, setting 8 on steam-jacketed kettle, 250°F on trunnion kettle).
9. Add ground beef to onions.
10. Cook meat for 7 minutes stirring frequently (225°F electric fry pan, setting 8 on steam-jacketed kettle, 250°F on trunnion kettle).
11. Drain off as much fat as possible using baster, then add seasonings.
12. Combine tomato paste and puree[c] and add to the ground beef mixture.
13. Cook mixture for 30 minutes (200°F on electric fry pan, 230-250°F in trunnion kettle, setting 7.5 on steam-jacketed kettle).
14. Combine cooked spaghetti and sauce in cooking utensil and cook until internal temperature reaches either 165 or 185°F, measured using a thermometer suspended in the center. Settings were adjusted up or down to achieve proper temperature in approximately a half-hour (lo to med-lo on electric range, settings 4.5-8 on steam-jacketed kettle, 190°F initially, later 350°F on trunnion kettle).

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[a] Trunnion kettle was used only for foodservice when heated to 165°F. Steps 5-9 were done before steps 1-4.

[b] Rehydrate onions by combining onions and water (50 ml, foodservice, 25 ml household) and let stand 20 minutes.

[c] Blend one can of whole tomatoes at a time in a blender set on puree setting for approximately 4 seconds, and weigh out correct amount.

Table A-3—Equipment used for this study

Large equipment
Balance, digital, Type A-200, Ainsworth, Ainsworth Division, Denver, Colorado.
Blender, Osterizer Cyclomatic, 10-speed, Model 877-01A, Oster Corporation, Milwaukee, Wisconsin.
Dazey Seal-A-Meal II, Model Sam 2, Dazey Products Company, Industrial Airport, Kansas 66031.
Digital Heat-Prober Thermometer, Platinum 392, Wahl Instruments, Culver City, California 90230.
Electric fry pan, Sunbeam, Model FPM-1 116009, Sunbeam Corporation, Chicago, Illinois.
Electric fry pan, 12", stainless steel, Farberware, Model 312B, Farberware, subsidiary of Walter Kidde and Company Incorporated, 1500 Bassett Avenue, Bronx, New York 10461.
Electric range, Whirlpool, Model RFE950P, Whirlpool Corporation, Benton Harbor, Michigan 49022.
Electronic controlled trunnion kettle, Model HK50, Hotpoint, Division of General Electric Corporation, Chicago Heights, Illinois 60411.
Food conveyor, electric, Blickman, Model ALS-4432, S. Blickman, Incorporated, Weehawken, New Jersey.
Food freezer, Frigidaire, Model UFD-150-59, Frigidaire Division, General Motors Corporation, Dayton, Ohio.
Food freezer, Frigidaire, Model UFD-18L, Frigidare Division, General Motors Corporation, Dayton, Ohio.
Instron Universal Testing Machine, Model 1122, Instron Engineering Corporation, Canton, Massachusetts 02021.
Refrigerator, Hotpoint, Model 12EG11A, Hotpoint, Division of General Electric Corporation, Chicago Heights, Illinois 60411.
Roaster, electric, Westinghouse, RD-414, Westinghouse Electric Company, Electric Appliance Division, Mansfield, Ohio.
Scale, Model 3710, Toledo Scale Company, Toledo, Ohio 43600.
Steam-jacketed kettle, Model TDB/6-10, 5-gallon, Dover Corporation/Groen Division, Elk Grove Village, Illinois.
Warming Tray, Catalog Number 33WT2, General Electric, Bridgeport, Connecticut.

Table A-4—Equipment used for this study

Small equipment
Aluminum pans, 12 1/2" × 10 3/8" × 4 1/16".
Baster, Foley.
Bread pans, aluminum, Mirro, 7 3/8" × 3 5/8" × 2 1/4".
Custard cups, 3 1/2" outside diameter, Anchor Hocking.
Custard cups, 5 3/8" outside diameter, Pyrex.
Fork, stainless steel, Foley.
Gallon measure, aluminum, Wear-Ever.
Glass casserole, Pyrex, 3 quart.
Rubber scraper, Rubbermaid.
Slotted spoon, stainless steel, Ecko.
Spaghetti fork, plastic.
Spaghetti pot, porcelain, 7 quart, 4 ounce.
Thermometer, -10-260°C range, Fisher.
Timer, Kodak.
Wooden spoon.

Fig. A-1—Sample score card used for sensory evaluation of spaghetti and meat sauce.

Name: ______________________________

Date: ______________________________

Please evaluate each sample of spaghetti with meat sauce for each of the attributes listed below. Place a vertical mark on the horizontal line to indicate your rating of each attribute. Label the vertical mark with the code number of the sample it represents.

Please evaluate the samples in the following order:

Appearance

(1) Moistness

|——————————————————————————————|

looks dry ... looks moist, juicy

(2) Spaghetti

|——————————————————————————————|

strands sticky and clumped together ... separate strands

Mouthfeel

(1) Dryness--gives sensation of a reduction in free fluids in oral cavity (wetness is the sensation of an increase in free fluids in oral cavity). Use approximately 1 tsp of sample.

|——————————————————————————————|

very wet ... very dry

Spaghetti Texture

(1) Firmness--force required to penetrate the spaghetti with the molar teeth.

|——————————————————————————————|

extremely soft ... extremely firm

Additional Comments

Flavor:

Greasiness:

Other:

Table A-5—Serving and testing schedule for sensory, chemical and physical measurements

Day	Treat-ment	Serving times for panelists 1,2	3,4	5,6	7,8	Thiamine	Instron	Code[b]
1	3	11:15am	12:00n	12:30pm	1:00pm		x[a]	514 HH185
	4	12:30	12:00	1:00	11:15			665 FS185
2	1	1:00	12:30	12:00	11:15	x	x	455 HH165
	2	11:15	1:00	12:00	12:30	x		638 FS165
3	1	12:30	1:00	11:15	12:00	x	x	126 HH165
	3	11:15	12:30	12:00	1:00	x		531 HH185
4	2	11:15	1:00	12:00	12:30		x	274 FS165
	4	11:15	1:00	12:30	12:00			722 FS185
5	2	11:15	12:00	12:30	1:00		x	669 FS165
	3	12:00	1:00	12:30	11:15			577 HH185
6	1	12:30	1:00	11:15	12:00	x	x	996 HH165
	4	12:00	12:30	1:00	11:15	x		496 FS185
7	3	12:00	1:00	11:15	12:30	x		359 HH185
	4	12:00	11:15	12:30	1:00	x	x	188 FS185
8	1	12:30	12:00	11:15	1:00			398 HH165
	2	1:00	12:00	12:30	11:15		x	689 FS165
9	1	1:00	12:00	12:30	11:15			127 HH165
	3	12:30	11:15	1:00	12:00		x	783 HH185
10	1	1:00	12:00	12:30	11:15			225 HH165
	4	12:30	11:15	12:00	1:00		x	821 FS185
11	2	1:00	11:15	12:30	12:00	x		668 FS165
	4	1:00	12:00	11:15	12:30	x	x	429 FS185
12	2	12:00	1:00	11:15	12:30	x		286 FS165
	3	1:00	11:15	12:00	12:30	x	x	384 HH185

[a] "x" indicates that the test was performed on sample on designated day.
[b] HH165 = Household 165°F; HH185 = Household 185°F; FS165 = Foodservice 165°F; FS185 = Foodservice 185°F.

Table A-6—Least squares means[a] for sensory data

Source of variation		Clumping	Firmness	Moist appearance	Mouthfeel
Foodservice procedures					
Temperature (°F)	Holding time (min)				
165	0	12.12	12.28	10.41	5.31
	45	11.28	7.90	9.55	7.24
	75	12.85	8.29	9.26	8.96
	105	8.65	6.08	9.24	7.36
185	0	11.28	9.38	8.63	7.45
	45	10.41	7.87	7.90	8.35
	75	9.15	6.08	8.38	8.22
	105	8.93	5.02	8.43	8.64
Household procedures					
Temperature (°F)	Holding time (min)				
165	0	13.34	10.58	9.25	7.63
	45	10.26	6.22	8.59	7.80
	75	11.06	5.79	8.23	7.62
	105	9.82	6.03	8.02	9.72
185	0	10.22	8.58	10.90	5.35
	45	8.64	6.06	8.06	8.22
	75	10.27	5.87	7.22	9.75
	105	8.87	4.93	7.09	8.60

[a] Twelve observations/mean.

Table A-7—Least squares means for physical and chemical data

Source of variation		Instron[a] Initial rupture force (kg)	Instron[a] Maximum force (kg)	Thiamin[b] As is (μg/g)	Thiamin[b] Dry weight (μg/g)
Foodservice procedures					
Temperature (°F)	Holding time (min)				
165	0	21.43	23.27	2.05	7.53
	45	19.76	21.69	2.17	8.12
	75	19.01	20.69	1.64	6.23
	105	18.34	20.44	1.54	5.82
185	0	21.72	23.26	1.63	5.98
	45	19.89	21.68	1.58	5.89
	75	18.97	20.51	1.58	6.02
	105	17.89	19.35	1.51	5.83
Household procedures					
Temperature (°F)	Holding time (min)				
165	0	21.36	23.57	1.87	6.52
	45	20.78	22.65	1.60	5.50
	75	20.70	22.90	1.83	6.36
	105	19.70	21.40	1.77	6.17
185	0	20.66	22.23	1.59	5.62
	45	18.57	20.06	1.58	5.44
	75	18.74	20.39	1.60	5.55
	105	18.07	19.48	1.59	5.58

[a] Six observations/mean.
[b] Three observations/mean.

Table A-8—Least squares means[a] for sensory dryness (mouthfeel) for treatment × temperature × time

Source of variation	Holding times (min)			
	0	45	75	105
FS 165	5.31^{a}	7.24^{abc}	8.96^{c}	7.36^{abc}
FS 185	7.45^{abc}	8.35^{c}	8.22^{bc}	8.64^{c}
HH 165	7.63^{abc}	7.80^{abc}	7.62^{abc}	9.72^{c}
HH 185	5.35^{ab}	8.22^{c}	9.75^{c}	8.60^{c}

[a] Means in same column or row with same letter are not significantly different from each other ($p \leq 0.05$).

EFFECTS OF HOT-HOLDING TIME AND TEMPERATURE ON SENSORY QUALITY AND THIAMIN CONTENT OF SPAGHETTI AND MEAT SAUCE

by

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Effects of hot-holding time and temperature on sensory quality and thiamin content of spaghetti and meat sauce were investigated. Two quantities and procedures, household and foodservice, and two holding temperatures, 165°F and 185°F, were used to prepare and hold spaghetti and meat sauce for 0, 45, 75 and 105 minutes. Household quantities were held in a household gas oven and foodservice quantities in a heated cart. A balanced incomplete block experimental design was used with regard to the quantity (foodservice or household) prepared and the temperature (165° or 185°F) of hot-holding used. Chemical and physical measurements on the spaghetti included thiamin analysis and measurement of firmness by the Instron Universal Testing Machine (IUTM). Sensory characteristics, mouthfeel (dryness), moistness (appearance), clumping and firmness, were analyzed by an eight member trained panel using a 15 cm unstructured scale.

Treatment significantly influenced firmness of spaghetti. Foodservice quantity spaghetti was significantly firmer ($p \leq 0.05$) than spaghetti prepared by household procedures. Temperature of hot-holding caused significant differences in clumping and firmness; 185°F produced less firm, more clumped spaghetti ($p \leq 0.05$) than 165°F-held spaghetti. Length of holding time resulted in significant differences in clumping, firmness, mouthfeel (dryness), and appearance of moistness in spaghetti. Freshly prepared spaghetti was significantly firmer, more moist in appearance and mouthfeel than the spaghetti held 45, 75 or 105 minutes ($p \leq 0.05$). Spaghetti held 105 minutes exhibited greater clumping ($p \leq 0.05$) than the freshly prepared spaghetti and the spaghetti held 75 minutes.

Temperature was a significant factor influencing thiamin retention and altering firmness as measured by the IUTM peak heights. Spaghetti held at 165°F was firmer and had more thiamin according to the means (µg/g) than

the 185°F-held spaghetti. Thiamin retention (dry weight basis) and percent moisture were significantly higher using the foodservice quantities and methods than with household quantities and methods. Firmness, as evaluated by the IUTM, decreased with length of holding time. Both household and foodservice quantities of spaghetti held for 105 minutes were the least firm ($p \leq 0.05$) and the freshly prepared spaghetti was the most firm, based on initial rupture force. A significant treatment × temperature interaction was found, with spaghetti held at 165°F by household methods being the most firm ($p \leq 0.05$) and the household 185°F-held spaghetti the least firm ($p \leq 0.05$). Foodservice methods using either temperature produced spaghetti intermediate in firmness between spaghetti held at 165°F and 185°F by household methods.