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CHARACTERIZATION OF VARIOUS WHEAT STARCH IN PASTA DEVELOPMENT

Wen-Chieh Sung* and Martha Stone**

Key words: pasta, starch, surfactant, semolina.

ABSTRACT

Determination of pasta cooking quality was more dependent on a continuous protein network than the physicochemical properties of gelatinized starch. In the absence of coagulated protein, "starch pasta" strands fractured into small pieces and did not swell in contrast to pasta made from flour or semolina after 20 minutes cooking. The starch of semolina was not a key factor related to better cooking quality of pasta compared to starches of hard wheat, but the starch of soft wheat might down grade the cooking quality of pasta. The results of this experiment showed that surfactants, monoglyceride and sodium stearoyl lactylate, did not improve the quality of cooked pasta. They might just interact with protein and not starch, because the cooking quality of "starch pasta" became worse with the addition of monoglyceride. Swelling of cooked pasta was mainly due to the hydration of protein. Pasta swelled to twice its original diameter after 20 minutes cooking, but the diameter of cooked "starch pasta" did not change at all. Differences among various sources of wheat starches could be factors in functional characteristics of cooked pasta, but these differences are not as important as gluten strength and protein content.

INTRODUCTION

Researchers agree that protein content and gluten strength are primary factors influencing pasta quality [6, 9, 10, 23, 24, 29]. The role of starch in pasta cooking quality has been better understood in the last decade [7, 8, 11]. Although starch is considered as a less important factor in pasta cooking quality, starch gelatinization during pasta drying has a major contribution to pasta quality [17]. Surfactants are often added to pasta products to improve their texture and to reduce surface stickiness, but the effects of surfactants and their interactions with starch or protein are not clearly understood.

No significant differences in physicochemical characteristics were observed between physicochemical properties of hard wheat and durum wheat starches [27]. Sheu *et al*. [33] reported that macaroni cooking characteristics were greatly influenced by the interchange of gluten and water-soluble fractions. Nevertheless, interchange of starch and sludge fractions had only a small effect on the cooking qualities of pasta [33]. Banks and Greenwood [2] proposed that durum wheat pasta was better than soft wheat pasta in cooking qualities because of differences in flour granule size which influences starch gelatinized temperature.

A high concentration of leached amylose on the surface of cooked pasta during cooking may contribute to stickiness [12]. Therefore, if high amounts of amylose are leached by starch granules to the surface of cooked pasta and into cooking water the pasta is considered to be of poor quality. Researchers have reported on the interaction between starch and surfactants [19, 28]. It has been shown that amylose forms a complex, helical structure, with certain types of surfactants [19]. The insoluble amylose, remaining in starch granules, inhibits the solubility and swelling of gelatinizing starch. Thus, the decrease in surface stickiness of cooked spaghetti and the increase in surface firmness of cooked noodles can be explained by the reduction of amylose bound to surfactants, such as monoglyceride (MG) or sodium stearoyl lactylate (SSL). Matsuo *et al*. [25] observed that addition of 0.5% monoglycerides to semolina significantly decreased the surface stickiness of cooked spaghetti.

A hypothesis for this research was assumed that pasta made from semolina and hard wheat flour would have similar cooking quality. Soft wheat flour is not an ideal material for making good quality pasta. Differences between pasta and "starch pasta" have the potential to clarify the role of gelatinized starch and coagulated gluten in pasta. A better understanding of the role of starch from wheat flours could improve pasta processing and could allow use of non-conventional raw materials in pasta preparation.

For this research, it was also evaluated that surfactants in pasta interact with starch or with protein. And differences between pasta and "starch pasta" have

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potential to clarify the role of gelatinized starch and coagulated gluten in pasta.

MATERIALS AND METHODS

Semolina, hard wheat flour, and soft wheat flour were obtained from General Mills, Inc. (Minneapolis, MN). Semolina starch, hard wheat starch and soft wheat starch were isolated from flours using the procedure of Medcalf and Gilles [27]. A completed randomized block design with three flours was used for starch isolation. Starch was isolated in sufficient quantities from hard or soft wheat flours and semolina for four replications. Moisture, ash, protein crude fat contents of flours and starches, and mxograms of flour were determined according to AACC methods [1].

Physicochemical Properties of Flours and Starches

Falling number values were measured in triplicate with a Model 1400 Falling Number apparatus using AACC method 56-81B [1]. Mixograms (TMCO, Lincoln, Neb.) were run at 58% absorption made from 10.0 grams of various flours and 5.80 ml distilled water. A spring setting of 12 was used and samples were mixed for 7 minutes. Mixograms were characterized by peak time, maximum height, and the angles formed between the ascending and descending portions of the curve according to AACC method 54-40A [1]. Amylograph viscosity of various flours was measured using a Brabender Instrument (C.W. Brabender Instruments, Inc., South Hackensack, NJ) Visco/Amylo/Graph. Standard amylograms could not be obtained using a procedure with 100 grams flour and 420 ml distilled water. For this reason, a suspension of 52 grams flour and 420 ml distilled water was heated from 30°C to 90°C at a controlled rate of 1.5°C per minute, (bowl speed set at 75 rpm), held at this 90°C for one hour, then cooled at a rate of 1.5°C to 50°C. Amylograph viscosity of flours or starches also was measured using the Brabender Instrument (C.W. Brabender Instruments, Inc., South Hackensack, NJ) Visco/Amylo/Graph and recorded as Brabender Units (B.U.). Suspensions of 40.5 grams starch and 450 ml distilled water were heated as previous flour conditions. Solubility and swelling power of various flours and starches were evaluated at temperatures of 60, 70, 80, and 90°C following the method of Leach *et al*. [20]. Water binding capacities of flours and starch were evaluated at 20°C by the procedure of Medcalf and Gilles [27].

Iodine Affinity and Amylose of Various Starches

The percentage of iodine affinity of various wheat starches was determined according to the procedure of iodimetric determination of amylose [32]. The percent amylose was calculated assuming an affinity of 19.4 for pure amylose [22].

Pasta and Starch Pasta Preparation

A 200-gram sample of flour was mixed and extruded into a laboratory pasta maker (Popeil Pasta Products, Inc., Beverly Hills, CA) with a spaghetti die (1.85 mm diameter). “Starch pasta” preparation followed the method of Chen [3] for making mung bean starch noodles with slight modification. Wheat starch (190g) was mixed with gelatinized starch and extruded with the same spaghetti die for pasta control. Gelatinized starch was prepared by heating 10 g starch in adequate amount of water (about 100 ml) in a boiling water bath to form slurry dough in a pasta maker. Surfactants, monoglyceride of concentrated glyceryl monostearate (MG)(Eastman Chemical Company, Kingsport, TN) and sodium stearoyl lactylate (SSL)(ICI Canada Inc., Brantford, Ontario) at 0.5% of flour or starch weight, were also added to the flour or wheat starch to make pasta and “starch pasta” for the surfactant treatments.

Diameter of 50 individual strands of dry pasta or 50 individual strands of dry starch pasta was measured. Optimum cooking time was calculated as the time required for the white core within the pasta strand to disappear [30]. Cooking losses were determined with the methods of Van Everen *et al*. [34].

Strength of dry pasta and strength of dry starch pasta were tested by the TA.XT2 Texture Analyzer (Texture Technologies Corp., Scarsdale, NY) with a Warner Bratzler blade (Texture Technologies Corp., Scarsdale, NY). Firmness of the cooked pasta and “starch pasta” was measured as force in compression with the TA.XT2 Texture Analyzer and a special lexan pasta blade and plate (probe TA-47) to imitate the action of a tooth was used. Two strands of cooked samples were taken every five minutes up to 40 minutes of cooking and held in distilled water until measuring (within 5 minutes). Calibration distance for the blade was 6.0 mm and test distance was 5.7 mm with a test speed of 1.0 mm/sec. The slope of force versus time (g/sec.) was converted to units of firmness (g/mm). Three determinations were made per sample. TA.XT2 instrumental measurements were also conducted for stickiness of cooked pasta and “starch pasta” after 20 minutes cooking. A TA-10 probe (one half inch diameter AOAC cylinder) was used to assess stickiness. Adhesiveness was recorded from a tension measurement as the highest peak force and converted to units of N/m^2. Calibration distance for the probe was 16.0 mm and test distance was 15.0 mm with a test speed of 1.0 mm/sec. Five hundred grams of force was applied on the cooked sample for 2 seconds and then the probe returned to original height.

Sensory Evaluation of Pasta and Starch Pasta

Seven pounds of pasta and "starch pasta" were prepared in a semicommerical ITALPAST MAC 60 pasta maker (Italpast Inc., Fidenza, Italy). Cooked pasta and starch pasta samples were distributed evenly among plastic cups and served to 40 panelists within 5.0 minutes after draining had begun. Each panelist was asked to evaluate more than two strands. The firmness of cooked pasta was defined as the force required to bite completely through sample with incisors first bite. Adhesiveness to teeth was defined as force required to separate molar teeth after sample is compressed completely with molar teeth and held down briefly (evaluate during the first 2-3 chews). Test samples were compared to reference pasta samples.

Panelists were instructed to place a single vertical mark on an unstructured linear scale that reflected their perception of the intensity of a given attribute. Each line (13 centimeter) was anchored at the extreme ends with verbal descriptors indicating low or high intensities of the attribute. Sensory scores were derived from the vertical marks made on horizontal linear scales by measurement to the nearest 0.1 centimeter from the left endpoint of the line to the mark, and dividing by 6.5 centimeter, which was the numerical score of the reference pasta (R). Thirty-six male and female students between the ages of 18 and 30 who were enrolled in a sensory evaluation course were participants on the panel.

Statistical Analysis

A completely randomized block design was used with 4 replications per treatment with 3 subsamples per replication. Data were analyzed by analysis of variance programs using Statistical Analysis System [31]. Pearson correlation coefficients were used to determine the relationship between factors (solubility, swelling power, water binding capacity, amylose content, firmness and stickiness of cooked samples). Data obtained from sensory evaluation results also were statistically evaluated by analysis of variance with the Statistical Analysis System [31]. Least squares means were used to identify differences between treatments at a 5% significance level ($p < 0.05$).

RESULTS AND DISCUSSION

Proximate Composition of Various Flours and Starches

Table 1 lists proximate compositions of various flours and starches. Semolina and hard wheat flour had significantly ($p < 0.05$) higher protein contents 14.81% and 14.88%, respectively, than that of soft wheat flour (10.44%). Crude fat was not significantly different among various wheat starches.

Flour Analysis: Falling Number of Various Flours

The falling number values indicate relative viscosity of flour and it has been widely used to measure α-amylase activity of flour. The lower the falling number, the higher α-amylase activity using the starch in the flour as substrate. The mean falling number value of semolina over 1000 indicating low α-amylase enzyme activity or higher relative viscosity (Table 2). Low falling number of hard wheat flour is due to the addition of malted barley flour by the company to enhance the baking process. This results indicates all flours had no sprouted damaged problem.

Mixogram of Various Flours

Figure 1 is the mixing curves for durum wheat, hard wheat, and soft wheat at 58% absorption using spring setting of 12 for 7 minutes. The area under the curve is a measure of the work required to mix dough.

Table 1. Proximate composition of various flours and starches[a]

Sample	% Moisture	% Protein	% Fat	% Ash
Semolina	10.8a	14.8a	1.0a	1.0a
Semolina starch	7.5b	0.5d	0.5ab	0.2c
Hard wheat flour	9.2ab	14.9a	0.6ab	0.7b
Hard wheat starch	6.6b	0.6d	0.2b	0.1c
Soft wheat flour	10.2ab	10.4b	0.8ab	0.6b
Soft wheat starch	6.5b	0.8c	0.2b	0.2c

[a] All values were a mean of 4 replications with 3 sub-samples per replication.
Mean values with the same letter in the same column were not significantly different ($p \geq 0.05$).

Table 2. Mixogram measurements and falling number values[a] of various flours[b]

Sample	Peak time (min.)	Max. height (cm)	Angle 1 (°)[c]	Angle 2 (°)[d]	Falling number
Semolina	2.5a	6.4a	131.3a	2.8a	>1,000[e]a
Hard wheat flour	2.2a	5.0b	128.7a	2.7a	317.3b
Soft wheat flour	0.8b	3.6c	112.6b	2.1a	490.0c

[a] All values of mixogram measurements were a mean of four samples and all falling number values were a mean of three measurements.

[b] Mean values with the same grouping letter at the same column were not significantly different ($p \geq 0.05$).

[c] Angle 1 was the angle formed between the ascending and descending portion of the curve.

[d] Angle 2 was the angle formed between the horizontal and the descending portion of the curve.

[e] All semolina samples had falling number values over the equipment limit.

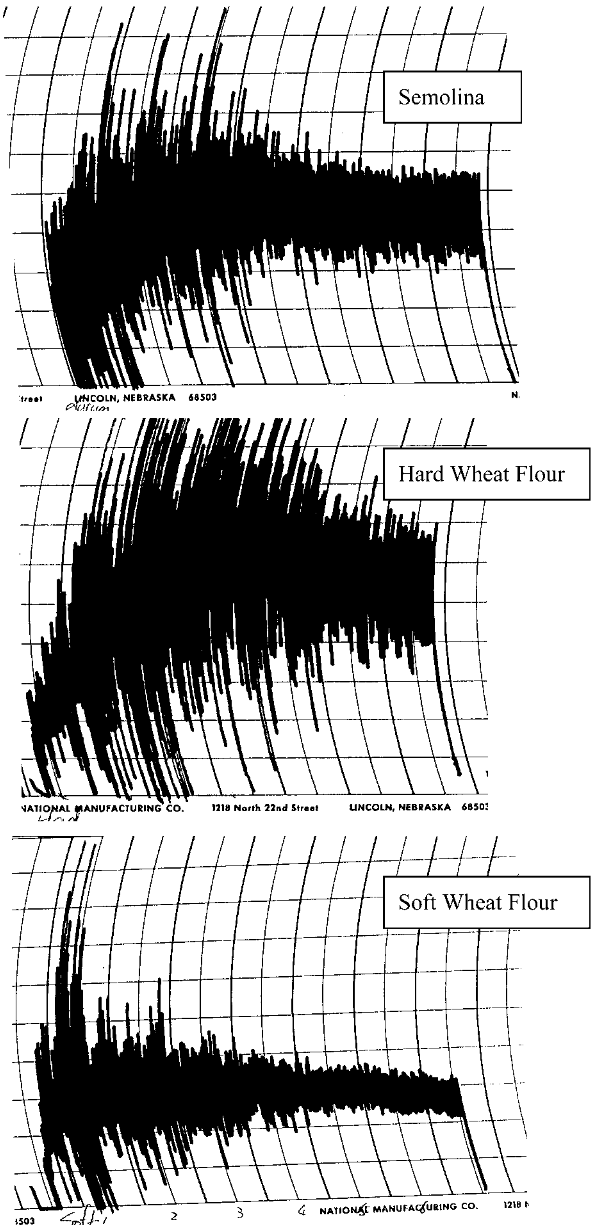

Fig. 1. Mixogram of various wheat flours.

Obviously, hard wheat flour required the highest work input and soft wheat flour needed least input energy to mix the flour. Table 2 lists the values of peak time, maximum height, and the angles formed between the ascending and descending portions of various wheat flours. The soft wheat flour required less mixing time to develop dough than hard wheat flour and semolina as shown by the peak time of mixograms. Soft wheat flour showed a shear-thinning phenomenon, after 5 minutes mixing. Hard wheat flour had a higher tolerance to overmixing and flour strength than semolina. These results indicate that hard wheat flour had the greatest gluten strength and soft wheat flour was a weak flour in comparison.

Amylogram of Various Flours and Starches

The viscoamylogram of various flours and starches is shown in Figure 2. Soft wheat starch had approximately twice greater Brabender viscosity than semolina starch and hard wheat starch. Hard wheat flour has lower viscograph consistencies than semolina and soft wheat flour indicating it has higher α-amylase activity (Figure 2). It was also confirmed by low falling num-

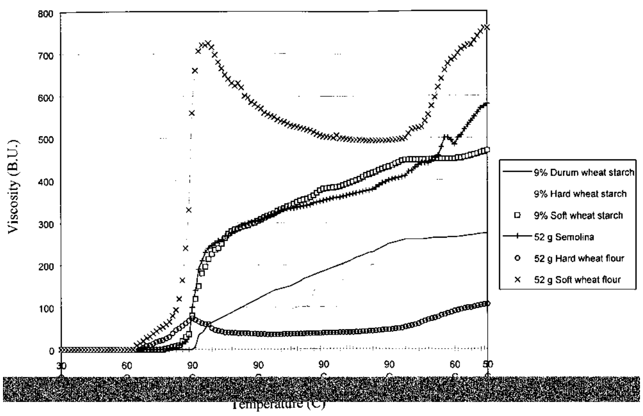

Fig. 2. Brabender viscoamylograph of various wheat flours and starches.

bers for the hard wheat flour (Table 2). Hard wheat flours milled in United States are low in α-amylase activity, so about 0.25% of malted barley or malted wheat flour is added [18]. Soft wheat flour had the higher viscosity than other wheat flours. Although, malted barley was added to hard wheat flour, the values measured for hard wheat starches isolated from hard wheat flours indicated slight differences in viscosity to durum wheat starch.

Swelling Power, Solubility and Water Binding Capacity

Results of water binding capacity are listed in Table 3. There were no significant differences between the water binding capacities of starch samples. This is in contrast to the results of Medcalf and Gilles [27], who reported starch from durum wheat had larger water-binding capacities than hard wheat and soft wheat starch. Starch granules of hard wheat flour and semolina were embedded in an irregularly shaped protein matrix, whereas starches from soft wheat flour are evident on the surface. Protein matrix may prevent semolina and hard wheat starch binding water. So semolina and hard wheat flour water bind capacities were lower than those from soft wheat flour and all starch samples ($p < 0.05$).

Values for swelling power at different temperatures are listed in Table 4. In general, swelling power increased with increasing temperatures for all flour and starch samples. Flours swelled less than starches extracted from the flours ($p < 0.05$). This indicated that protein matrix of flours without mixing bound less water than gelatinized starch. Semolina starch and hard wheat starch had similar swelling powers at all test temperatures. At 60°C, soft wheat starch swelled less than semolina starch, while soft wheat starch swelled significantly more at 80 and 90°C ($p < 0.05$). This indicates soft wheat starch swell more rapid than the other two variety starches during cooking had more potential to breakdown the continuous gluten network than semolina and hard wheat starch during cooking. This might partially explain the cooking loss of soft wheat pasta is higher than semolina and hard wheat pasta.

Solubility data for various flours and starches at different temperature are presented in Table 5. In general, starch solubility increased with increasing temperatures (60 to 80°C), and flour solubility increased with increasing temperatures (60 to 70°C) then both decreased solubility with increasing temperatures to 90°C. A possible reason for the decrease in solubility with increasing temperature in all flour and starch samples is that the coagulated protein matrix and gelatinized starch can prevent leaching of soluble material into water. All starch samples had significantly lower solubility but higher swelling power value than all flours. This indicates without continuous gluten network, gelatinized starch has better ability to prevent leaching

Table 3. Water binding capacitiesa of various wheat flours and starches[b]

Sample	Water binding capacity (%)
Semolina	207.5a
Hard wheat flour	205.3a
Soft wheat flour	222.7b
Semolina starch	224.0b
Hard wheat starch	224.4b
Soft wheat starch	227.0b

[a] All values were a mean of 4 replications with 3 sub-samples per replication.
[b] Mean values with the same letter in the same column were not significantly different ($p \geq 0.05$).

Table 4. Swelling powers[a] of various wheat flours and starches[b] at different temperatures

	Swelling power			
Sample	60°C	70°C	80°C	90°C
Semolina	3.1a	4.0a	4.9a	5.7a
Hard wheat flour	2.8a	5.1b	5.8c	6.9ab
Soft wheat flour	2.9a	5.1b	6.2bc	7.4b
Semolina starch	4.5b	5.9c	6.4b	7.6b
Hard wheat starch	4.4b	6.1c	6.5b	8.0b
Soft wheat starch	4.0c	6.1c	6.8d	9.1c

[a] All values were a mean of 4 replications with 3 sub-samples per replication.
[b] Mean values with the same letter in the same column were not significantly different ($p \geq 0.05$).

Table 5. Solubility[a] of various wheat flours and starches[b] at different temperatures

	Solubility (%)			
Sample	60°C	70°C	80°C	90°C
Semolina	9.7a	13.1a	10.3a	8.5a
Hard wheat flour	14.6b	25.5c	20.6c	13.0c
Soft wheat flour	11.5a	12.2a	11.1a	8.3a
Semolina starch	2.5c	2.6b	3.5b	4.4b
Hard wheat starch	2.4c	3.8b	5.3b	4.5b
Soft wheat starch	2.8c	8.2d	9.4a	4.2b

[a] All values were a mean of 4 replications with 3 sub-samples per replication.
[b] Mean values with the same letter in the same column were not significantly different ($p \geq 0.05$).

Table 6. Functional characteristics after 20 minutes cooking starch pasta and pasta[ab]

Sample	% Cooked weight	% Cooking loss	Stickiness (N/m^2)[c]	Firmness (g/mm)
Pasta samples				
Semolina	313.5a	6.2a	1150.5a	44.9a
Hard wheat flour	313.4a	8.2a	3248.9b	44.4a
Soft wheat flour	389.6a	8.8a	6108.6b	28.4b
Semolina + MG	312.0a	6.6a	1248.6a	39.8a
Semolina + SSL	311.1a	6.9a	1548.0ab	39.3a
Starch pasta samples				
Semolina starch	357.4b	26.6b	729.8a	20.8ce
Hard wheat starch	439.7b	19.3b	9558.9b	18.4cde
Soft wheat starch	310.6c	41.7c	30076.1c	14.3d
Semolina starch + MG	283.1d	51.9d	43552.4c	14.0cd
Semolina starch + SSL	434.4b	22.8b	9342.0b	22.0e

[a] All values were a mean of 4 replications with 3 sub-samples per replication.
[b] Mean values with the same grouping letter at the same column were not significantly different ($p \geq 0.05$).
[c] Data were analyzed on log10 scale, and least squares means were reported.

Table 7. Iodine affinities[a] and amylose contents[b] of various wheat starches

Sample	% Iodine affinity	% Amylose
Semolina starch	3.8a	19.4a
Hard wheat starch	3.6a	18.7a
Soft wheat starch	3.8a	19.4a

[a] All values were a mean of 4 replications with 3 sub-samples per replication.
[b] Amylose content was converted from iodine affinity assuming an affinity of 19.4 for pure amylose. Mean values with the same grouping letter at the same column were not significantly different ($p \geq 0.05$).

of soluble material into water than coagulated protein matrix. Correlation analysis showed water binding capacity significantly ($p < 0.05$) related to swelling power ($r = 0.80$) of various starches at 90°C. Higher water binding capacity of starches at 20°C, produced higher swelling powers for the starches. Starches have higher water binding capacity at 20°C will have lower solubility at 90°C. Water binding capacity of flour was negative by correlated to solubility of flour at 90°C. Flour had high water binding capacity and its solubility was also high. Although the absence of complete gluten development during pasta processing was reported by several authors [4, 13, 14, 26], the process of pasta making significantly decreased the solid loss of pasta compared to “starch pasta” (Table 6)($p < 0.05$).

Functional characteristics of 20 minutes cooking “starch pasta” and pasta are presented in Table 6. All pasta samples had significantly lower cooked weight and solid loss than “starch pasta”. Continuous gluten network protein prevented the soluble starch into water better than gelatinized starch alone. Soft wheat pasta had higher cooking loss and cooked weight than semolina and hard wheat pasta, but they were not significantly different. Soft wheat “starch pasta” has significantly higher cooking loss and less cooked weight than semolina and hard wheat “starch pasta”. All pasta samples except pasta made from soft wheat were significantly firmer than “starch pasta”. This indicates coagulated gluten network played the role of cooked pasta firmness (Table 6). Addition of surfactants can soft the cooked pasta, but it is not significantly different ($p > 0.05$).

Iodine Affinity and Amylose Content of Starches

Table 7 lists the iodine affinity and amylose content of various wheat starches. No significant differences were found among various wheat starches in iodine affinity and amylose content. D’Appolonia et al. [5] reported that the amylose content for wheat starch was between 17 to 29%. Lii and Lineback [21] reported 4.49% to 4.61% for iodine affinity and 19.23% to 19.61% for amylose content in wheat starch. Medcalf and Gilles [27] also reported a range from 23.4 to 27.6% amylose in hard wheat and durum wheat starches by potentiometric titration. Although they reported that durum wheat starches tended to be on the high end of the range, no significant differences were observed between wheat varieties. Iodine affinity and amylose content did not show main effect on starch physicochemical effects and pasta cooking qualities.

Table 9. Firmness[a] (g/mm) of various cooked pasta and starch pasta[b]

	Cooking time							
Sample	5 minutes	10 minutes	15 minutes	20 minutes	25 minutes	30 minutes	35 minutes	40 minutes
Pasta samples								
Semolina	206.6ac	81.0a	57.2a	44.9a	37.9a	35.0a	30.0a	24.9a
Hard wheat flour	251.9a	82.2a	57.2a	44.4a	34.4ad	34.4a	29.8a	26.0a
Soft wheat flour	146.6cd	51.6c	35.9c	28.4b	22.6b	19.3b	16.5b	9.3b
Semolina + MG	193.1a	67.1e	46.9e	39.9a	31.5d	27.1d	23.2c	20.9a
Semolina + SSL	178.0c	79.4a	47.9e	39.3a	36.5a	33.7a	32.7a	26.7a
Starch pasta samples								
Semolina starch	91.6bd	30.0b	28.7b	20.8ce	20.4b	17.6b	13.3b	10.9b
Hard wheat starch	53.3b	29.7b	21.9d	18.4cde	17.0b	15.1b	10.3b	7.0b
Soft wheat starch	146.6bd	27.0bd	18.9d	14.3d	9.5c	6.0c	4.2d	6.5b
Semolina starch + MG	30.1b	16.6df	16.6d	14.0cd	not available		not available	
Semolina starch + SSL	36.4b	24.4bf	23.4bd	22.0e	18.1b	11.9b	11.1b	8.2b

[a] All values were a mean of 4 replications with 3 sub-samples per replication.
[b] Mean values with the same letter in the same column were not significantly different ($p \geq 0.05$).

Functional Characteristics of Starch Pasta and Pasta

Dry "starch pasta" and pasta strength and diameter are presented in Table 8. The strength of dry "starch pasta" was not significantly different, but the diameter of pasta was significantly larger than that of "starch pasta" ($p < 0.05$).

Optimal cooking time was determined by the disappearance of white core in pasta. Optimal cooking time for "starch pasta" (10 minutes) was shorter than that for pasta (20 minutes). Grzybowski and Donnely [16] stated that starch gelatinization was more rapid at relatively lower protein levels than at higher protein contents. It takes longer for the water to penetrate the protein network when it was more extensively denatured. Feillet [15] proposed that the delay of starch gelatinization beneath the surface of pasta during extended cooking periods was due to the compact structure of hydrophobic protein.

Firmness of various cooked pasta and "starch pasta" cooked over 40 minutes is shown at Table 9. Both hard wheat pasta and semolina pasta were resistant to overcooking and had similar firmness values at all cooking times. Soft wheat pasta was significantly softer and was not resistant to overcooking. Both surfactant treatments showed a decrease in firmness of cooked pasta but it was not significant ($p > 0.05$). None of the surfactants showed an improvement in firmness of cooked "starch pasta". All starch pasta dissolved into water after 25 minutes cooking with addition of 0.5% MG treatment. The firmness of cooked soft wheat "starch pasta" was also softer than semolina and hard wheat "starch pasta" ($p < 0.05$) after 25 minutes cook. This indicated that the soft wheat starch product was different from the semolina starch product. Firmness values for 20 minutes cooked "starch pasta" was negatively correlated to solid loss ($r = -0.65$) and stickiness($r = -0.58$) of cooked "starch pasta". The firmer the cooked "starch pasta", the lower the solid loss and stickiness value of "starch pasta". Correlation analysis for firmness of cooked products indicated that softer cooked samples had higher cooking weight, higher solid loss and were more sticky.

Table 8. The strength and diameter of dry starch pasta and pasta made with various starches and flours[ab]

Sample	Strength (g)	Diameter (mm)
Pasta samples		
Semolina	2100.7a	1.9a
Hard wheat flour	1965.4a	1.9a
Soft wheat flour	850.4b	1.8b
Semolina + MG	1852.1ac	1.9a
Semolina + SSL	1891.2a	1.9a
Starch pasta samples		
Semolina starch	1903.4a	1.6c
Hard wheat starch	1537.1ac	1.6c
Soft wheat starch	1289.0bc	1.6c
Semolina starch + MG	1145.4b	1.5d
Semolina starch + SSL	1083.6b	1.6c

[a] All values were a mean of 4 replications with 50 sub-samples per replication.
[b] Mean values with the same grouping letter at the same column were not significantly different ($p \geq 0.05$).

Neither surfactant, when used at the 0.5% level,

Table 10. Textural attributes[a] of subjective and objective evaluation of cooked pasta and starch pasta

	Subjective	
	Firmness	Stickiness
Pasta	1.0a	1.0b
Starch pasta	0.8a	0.9b
	Objective	
	Firmness (g/mm)	Stickiness (N/m^2)
Pasta	28.6c	200.0d
Starch pasta	25.1c	90.3e

[a] Mean values with the same grouping letter within a column were not significantly difference ($p \geq 0.05$). Panel numbers for subjective cooked pasta and starch pasta firmness and stickiness analysis were 36.

significantly improved cooking loss of pasta. Monoglyceride dramatically increased the percentage of cooking loss in "starch pasta" ($p < 0.05$). This indicates that use of 0.5% monoglyceride could not improve the quality of pasta if it interacted with starch. Another surfactant, sodium stearoyl-2-lactylate, did not influence the cooked weight and cooking loss in pasta and "starch pasta". Only semolina "starch pasta" had a lower stickiness value than semolina pasta after 20 minutes cooking, but it was not statistically different ($p > 0.05$). Soft wheat "starch pasta" was significantly stickier than semolina and hard wheat "starch pasta" ($p < 0.05$). Again, MG (0.5%) increased the stickiness of "starch pasta", but it did not influence the stickiness of cooked pasta. Stickiness of cooked pasta may be contributed partially by gelatinized starch. "Starch pasta" became very soft after 20 minutes cooking. Surfactants did not significantly influence the firmness of cooked pasta in relation to coagulated protein or gelatinized starch. In the absence of coagulated protein, "starch pasta" strands fractured into small pieces and did not swell in contrast to pasta made from flour after 20 minutes cooking.

Sensory Evaluation of Pasta and Starch Pasta

From 40 sensory panelists, thirty-six score sheets were available for statistical analysis. Table 10 shows values for textural attributes of cooked samples. Semolina "starch pasta" was less firm and less sticky than the pasta reference from objective results (texture analyzer measurement). Both subjective and objective results showed the firmness of gelatinized starch was less firm but it is not significantly different to the firmness of cooked pasta, hydrated gluten and gelatinized starch (Table 10).

Pasta swelled to twice of its original diameter after 20 minutes cooking, but the diameter of cooked "starch pasta" did not change significantly. Therefore, the swelling of cooked pasta was due to the hydration of gluten and not due to the gelatinization of starch. The function of coagulated gluten preventing the penetration of water into the center core during cooking and making the optimum cooking time longer was better than gelatinized starch.

Although no significant differences in physicochemical characteristics were observed between hard wheat and durum wheat starches in our work, soft wheat starch seems more obviously has higher solubility, swelling power at higher testing temperature than the other two varieties. Especially, when various starches were processed to "starch pasta", the qualities of cooked soft wheat starch pasta is worse than the other two starch pasta. It explains gelatinized characteristics of starch are also a factor influencing the qualities of cooked pasta. We suggest when durum wheat is in short supply because of disease or expensive hard wheat flour is a better substitute than soft wheat flour to produces good pasta. Studies in this research has been conducted on the difference between starch pasta and pasta. This work indicates that protein content and gluten are primary factors influencing pasta quality, but the gelatinized properties of starch should be also considered as a partial factor.

REFERENCES

1. AACC, "Approved Methods of the AACC (10th ed.)," St. Paul, Minnesota (1995).
2. Banks, W. and Green, C.T., "Fractionation of the Starch Granule, and the Fine Structures of its Components," *Starch and its Components*, Aberdeen University Press, Edinburgh, pp. 242-273 (1975).
3. Chen, C.Y., "The Noodle Qualities and Physicochemical Properties of Various Searches Isolated by Wet Process," M.S. Thesis, National Taiwan University, Taipei, Taiwan, R.O.C. (1978).
4. Cunin, C., Handschin, S., Walther, P., and Escher, F., "Structural Changes of Starch during Cooking of Durum Wheat Pasta," *Lebensm. Wiss Technol.*, Vol. 28, No. 3, pp. 323-328 (1995).
5. D'Appolonia, B.L., Gilles, K.A., Osman, E.M., and Pomeranz, Y., "Carbohydrates," *Wheat Chemistry and Technology*, Vol. 3, Y. Pomeranz (Ed.), Am. Assoc. Cereal Chem. Inc., St. Paul, Minnesota, pp. 277-372 (1971).
6. D'Egidio, M.G., Mariani, B.M., Nardi, S., Novaro, P., and Cubadda, R., "Chemical and Technological Variables and Their Relationships: A Predictive Equation for Pasta Cooking Quality," *Cereal Chem.*, Vol. 67, No. 4,

pp. 275-281 (1990).

7. Delcour, J.A., Vansteelandt, J., Hythier, M.-C., Sindic, M., and Deroanne, C., "Fractionation and Reconstitution Experiments Provide Insight into the Role of Gluten and Starch Interactions in Pasta Quality," *J. Agric. Food Chem.*, Vol. 48, pp. 3767-3773 (2000).
8. Delcour, J, A., Vansteelandt, J., Hythier, M.-C., and Abecasis, J., "Fractionation and Reconstitution Experiments Provide Insight into the Role of Starch Gelatinization and Pasting Properties in Pasta," *J. Agric. Food Chem.*, Vol. 48, pp. 3774-3778 (2000).
9. Dexter, J.E. and Matsuo, R.R., "The Spaghetti-Making Quality of Developing Durum Wheats," *Can. J. Plant Sci.*, Vol. 57, pp. 7-16 (1977).
10. Dexter, J.E. and Matsuo, R.R., "Influence of Protein Content on Some Durum Wheat Quality Parameters," *Can. J. Plant Sci.*, Vol. 57, pp. 717-727 (1977).
11. Dexter, J.E. and Matsuo, R.R., "Effect of Starch on Pasta Dough Rheology and Spaghetti Cooking Quality," *Cereal Chem.*, Vol. 56, No. 3, pp. 190-195 (1979).
12. Dexter, J.E., Matsuo, R.R., and MacGregor, A.W., "Relationship of Instrumental Assessment of Spaghetti Cooking Quality to the Type and the Amount of Material Rinsed from Cooked Spaghetti," *J. Cereal Sci.*, Vol. 3, pp. 39-53 (1985).
13. Dexter, J.E. and Matsuo, R.R., "Changes in Semolina Proteins During Spaghetti Processing, " *Cereal Chem.*, Vol. 54, pp. 882-894 (1977).
14. Dexter, J.E. and Matsuo, R.R., "The Effect of Gluten Protein Fractions on Pasta Dough Rheology and Spaghetti-Making Quality," *Cereal Chem.*, Vol. 55, No.1, pp. 44-57 (1978).
15. Feillet, P., "Proteins. Evaluation and Measurements of Wheat Quality," *Wheat Chemistry and Technology*, Y. Pomeranz (Ed.), Am. Assoc. Cereal Chem. Inc., St. Paul, Minnesota, pp. 507-547 (1988).
16. Grzybowski, R.A. and Donnelly, B.J., "Starch Gelatinization in Cooked Spaghetti," *J. Food Sci.*, Vol. 42, pp. 1304-1305, 1315 (1977).
17. Guler, S., Koksel, H., and Ng, P.K.W., "Effects of Industrial Pasta Drying Temperatures on Starch Properties and Pasta Quality," *Food Res. Inter.*, Vol. 35, pp. 421-427 (2002).
18. Hoseney, R.C. (Ed.), "Cereal Starch," *Principles of Cereal Science and Technology*, Am. Assoc. Cereal Chem. Inc., St. Paul, Minnesota, pp. 36-68 (1992).
19. Krog, N., "Amylose Complexing Effect of Food Grade Emulsifiers," *Starch/Starke*, Vol. 23, pp. 206-210 (1971).
20. Leach, H.W., McCowen, L.D., and Schoch, T.J., "Structure of Starch Granule I. Swelling and Solubility Patterns of Various Starches," *Cereal Chem.*, Vol. 36, pp. 534-544 (1959).
21. Lii, C.Y. and Lineback, D.R., "Characterization and Comparison of Cereal Starches," *Cereal Chem.*, Vol. 54, pp. 138-149 (1977).
22. Lornez, K. and Kulp, K., "Steeping of Barley Starch," *Starch/Starke*, Vol. 36, No. 4, pp. 116-121 (1984).
23. Malcolmson, L.J., Matsuo, R.R., and Balshaw, R., "Textural Optimization of Spaghetti Using Response Surface Methodology: Effects of Drying Temperature and Durum Protein Level," *Cereal Chem.*, Vol. 70, No. 4, pp. 417-423 (1993).
24. Matsuo, R.R. and Irvine, G.N., "Effect of Gluten on the Cooking Quality of Spaghetti," *Cereal Chem.*, Vol. 47, pp. 173-180 (1970).
25. Matsuo, R.R., Dexter, J.E., Boudreau, A., and Daun, J. K., "The Role of Lipids in Determining Spaghetti Cooking Quality," *Cereal Chem.*, Vol. 63, pp. 484-498 (1986).
26. Matsuo, R.R., Dexter, J.E., and Dronzek, B.L., "Scanning Electron Microscopic Study of Spaghetti Processing," *Cereal Chem.*, Vol. 55, No 5, pp. 744-753 (1978).
27. Medcalf, D.G. and Gilles, K., "Wheat Starches. I. Comparison of Physicochemical Properties," *Cereal Chem.*, Vol. 42, pp. 558-567 (1965).
28. Mohri, Z., "Interaction between Starch and Fatty Acid Esters in Frozen Starch Noodles," *Agric. Biol. Chem.*, Vol. 44, 1455-1459 (1980).
29. Novaro, P., D'Egidio, M.G., Mariani, B.M., and Nardi, S., "Combined Effect of Protein Content and High-Temperature Drying Systems on Pasta Cooking Quality," *Cereal Chem.*, Vol. 70, No. 6, pp. 716-719 (1993).
30. Oh, N.H., Seib, P.A., Deyoe, C.W., and Ward, A.B., "Noodles, I. Measuring the Textural Characteristics of Cooked Noodles," *Cereal Chem.*, Vol. 60, No. 6, pp. 433-438 (1983).
31. SAS Institute, Inc., "SAS User's Guide, Version 6 Edition," SAS Institute, Cary, North Carolina (1995).
32. Schoch, T.J., "Iodimetric Determination of Amylose," *Methods in Carbohydrate Chemistry*, Vol. 4, Whistler, R.L. (Ed.), Academic Press, New York and London, pp. 157-160 (1964).
33. Sheu, R.Y., Medcalf, D.G., Gilles, K.A., and Sibbit, L. D., "Effect of Biochemical Constituents on Macaroni Quality. I. Differences between Hard Red Spring and Durum Wheats," *J. Sci. Food Agric.*, Vol. 18, pp. 237-240 (1967).
34. Van Everen, K., Maga, J.A., and Lorenz, K., "Spaghetti Products Containing Dried Distillers Grain," *Develop Food Sci.*, Vol. 29, pp. 551-563 (1992).