EFFECTS OF SURFACTANTS, SOY PRODUCTS, AND SALT ON AMYLOGRAPH PROPERTIES OF FLOUR SUSPENSIONS AND COOKING QUALITY OF NOODLES

by

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INTRODUCTION

Historically, pasta products were reportedly introduced to Europe by Marco Polo on return from his renowned journey to China. At that time, pasta products were probably produced by sheeting. Pasta, dried formed dough, possibly ranks close to "bread" as a universially accepted food. It is one of the simplest of foods. In their attempts to utilize cereals, Asiatic people partially refined the cereal and "reconstituted" it in a storable and readily prepared form. Present day pasta products are basically wheat that has been refined and reformed (1-6).

The flour used for the production of pasta can vary widely. Actually, food forms we call macaroni, spaghetti, noodles, etc., can be, and are, produced from other raw materials. In the United States the Federal Standards of Identity limit the basic material to wheaten products; i.e., semolina, durum flour, farina, flour or a blend of two or more of these materials. Durum (*Triticum durum*) is the best suited of all wheats for pasta and also yields the highest quality finished product. In view of these factors, European countries require by law that durum be used for pasta products. However, this is not the case for Asiatic and African countries where durum is in short supply.

The quality of the raw materials for good pasta production is very important. Semolina is the leader. Semolina is defined in the Standards of Identity as a granular material, milled from durum wheat, all of which pass through a U. S. No. 2 sieve and no greater than three per cent will pass through a U. S. 100 sieve (3-7).

Although durum semolina is most renowned in satisfying specifications of raw materials for pasta production, wheat (*Triticum vulgare*) and other materials such as rice, corn and certain varieties of legumes are also used in Asiatic and African countries (3-6).

Noodles may be defined as the product which is produced in ribbon shape and which contains not less than 5.5 per cent by weight of the solids of egg or egg yoke as a percentage of the total solids in the finished product.

In the United States and European countries noodle production differs from the production of other pasta products in that they are generally made from flour and eggs. Soft wheat flour is commonly used in making noodles in Asia and soft wheat flours are usually low in protein.

A shortage of protein is a serious problem in many of the developing countries. For increasing protein and vitamin intake and for enriching the products, soy flour, fish protein concentrates, rapeseed flour, peanut meal and legume concentrate are added in making pasta products. Adding soy flour to semolina not only improves the nutritional quality of pasta, but also increases the firmness of pasta (8).

The quality test of pasta products is their behavior on cooking, the extent to which they become pasty or sticky during cooking. To eliminate pastiness in these products, distilled monoglyceride and soybean lecithin are added in manufacturing pasta products (9-11).

Surface-active agents are widely used in the food industry to improve food values and to suit consumer preference (12). It is well-known that surfactants have the ability to form complexes with the amylose components of the starch molecules (13-15).

The objectives of this study are to investigate: 1) the use of surfactants and soy products to improve the nutritive and cooking quality of wheat flour noodles by eliminating their stickiness and retaining their firmness, in noodles and in pasting properties of flour suspensions, 2) the effect of salt on cooking quality, and 3) the evaluation of soft wheat flour in manufacturing noodles.

REVIEW OF LITERATURE

Quality Evaluation of Pasta Products

The term "quality" as applied to pasta products can only be defined on the basis of factors contributing to consumer preference. The characteristics of a good pasta according to LeClerc (3) are hardness, brittleness, translucency, elasticity, and a rich amber color. The fracture should be glassy, long pieces should have sufficient pliability to allow considerable bending before breaking. The behavior on cooking is most important; a good pasta product, upon normal cooking, will swell from two to four times its original size, retain its shape and firmness, not become pasty, but possess a very pleasing odor. Important factors associated with pasta quality are: 1) color, vitreousness and translucency, 2) mechanical strength, and 3) cooking characteristics such as water absorption, swelling, disintegration, and tenderness.

Color. The tradition has it that if pasta was yellow, it was a superior product. This tradition is still current today, although there are a number of other wheats which will produce pasta but do not yield a yellow product.

The factors associated with a desirable pasta color are quite complex, involving not only the pigment content but also translucency and vitreousness which, in turn, are apparently dependent upon the quantity and quality of the protein, the degree of hydration of starch, and the differences in processing techniques (16, 17). Clear deep-yellow pasta is obtained from semolina of high yellow-pigment content and low lipoxidase activity, which has been milled to a fairly low extraction (60-65%). As semolina extraction rate increases, or as lower grades of semolina or flour are used, the color becomes increasingly brownish. Low-grade flours generally give a chocolate color.

Small differences in pasta color are most readily detected by visual observation; therefore, pasta color is measured by visual comparison against standard samples. Errors in visual measurement arise due to changes in color of standard samples with age, differences in concept of color among judges, and lack of precision in describing the color.

In an attempt to eliminate these errors, objective measurements of pasta color have been introduced. Fifield et al. (18) and Corneluissen et al. (19) measured the yellow color of moist durum semolina with Munsell Spinning Disk. Matz and Larsen (20) tested the accuracy of several photoelectric instruments for measuring the color of durum semolina and found that the Hunter color-difference meter, the photovolt reflectance meter, and the Densichron reflectance meter gave good results; but reported no measurements of the color of spaghetti or noodles or other finished products. However, Matsuo and Irvine (21) reported differences in the reflectance spectra between yellow and brown pasta, using the Ten Select Ordinated Method. Later, Walsh et al. (22) also measured the spaghetti color with a tristimulus colorimeter.

Even though small differences in pasta color are most readily detected by visual observation, optical reflectance data of objective measurement are preferable.

Mechanical strength. A high degree of mechanical strength is desirable in pasta products in order to minimize breakage. Binnington and Geddes (16) and Holliger (23) described machines for recording breaking strength, but the rather poor reproducibility of such tests generally limited their usefulness in establishing relations between other factors and breaking strength.

As indices of mechanical strength, measurements of tensile strength, crushing strength, and transverse and torsional breaking strength might be carried out but, for pasta products, a test of the transverse breaking strength appears the most suitable. Also tensile strength tests are not feasible because of the difficulty of clamping without breaking, but Holliger (23) suggested that the tensile strength of uncooked spaghetti was related to firmness.

Strong, elastic pasta usually indicates a well-processed product of reasonably high protein content and high grades of durum. However, the physical properties of the dried product give little indication of cooking quality and hence are of limited value in evaluating finished products.

Cooking characteristics. The cooking quality of pasta products is the major criterion by which pasta consumer may measure quality and acceptability. When the product is cooked in boiling water, it should maintain its shape without falling apart or splitting and should cook to a firm consistency free of a slimy, sticky surface film. The cooking water should be relatively free of starch and the products should be resistant to disintegration due to over-cooking.

The test of pasta cooking quality is usually made on a fixed quantity of dried pasta product with a fixed volume of water held at a constant boiling temperature. Spaghetti is the preferred test material as it is considerably more sensitive than other pasta products. After fixed periods of boiling, the test involves measurement of per cent swelling, quantity of residue in the cooking water and tenderness of the products.

For measuring firmness, most often the "bite test" and taste panel test are used, but these tests are not reliable because they are subject to individual bias.

Several workers (17, 23-25) have introduced objective methods for measuring pasta firmness. Such tests are much more preferable and reproducible than organoleptic assessments. However, no data on texture of cooked spaghetti were given. Matsuo and Irvine (26) designed an apparatus which would simulate the bite test for testing the tenderness of cooked spaghetti. They claimed that the apparatus is sufficiently sensitive to differentiate spaghetti made from different durum varieties. Later, Walsh (27) developed an Instron Universal tester for measuring the firmness of cooked spaghetti. His results showed that the shear test had a high positive correlation with panel scores for spaghetti firmness.

Most pasta manufacturers generally believe that differences in swelling and residue between pasta products made from durum semolinas of various origins are often small; but when comparisons are made between durum products and those made from soft wheats, the differences become highly significant. However, differences in tenderness at optimum cooking time can vary quite widely among durum products.

Many factors, such as processing conditions, age, handling, and storage can influence pasta cooking quality. Recent workers have suggested that the amount of wheat proteins influences pasta cooking quality. Holliger (28) and Matweef (29) reported that gluten quantity was related to spaghetti cooking quality. Sheu et al. (30) interchanged the biochemical constituents of durum and hard red spring wheat and found that gluten of medium strength appeared to produce spaghetti of optimum cooking quality. From the composition of protein fraction, Walsh and Gilles (32) showed that protein composition was related to several spaghetti quality factors; high glutenin and albumin but low gliadin contents were associated with high spaghetti firmness. Matsuo et al. (33) studied the effect of the protein content of wheat and proteins from other sources when added to a control semolina. Their results indicated protein content should be at least 11% for acceptable cooking quality of products and can be increased by addition of protein from other sources. However, all proteins did not improve the cooking quality. Of various proteins tested, only egg albumin and wheat gluten improved the cooking quality. Rapeseed flour and fish protein concentrate impaired the cooking quality and soy flour had little effect.

Dahle and Muenchow (34) removed various amounts of lipid and protein by extracting them from spaghetti with water-saturated butanol, 70% ethanol, or three concentrations of acetic acid. The extracted samples were cooked for different periods of time and then the cooking characteristics were compared. Removal of lipid or protein increased amylose concentration in cooking water. The cooking quality of spaghetti was impaired more by protein removal than lipid removal. They concluded that protein was an essential structural component of spaghetti and other pasta products. Without protein, the strands tended to disintegrate and to lose their form on cooking. The lipid supplemented the function of protein and minimized other consequences of cooking such as stickiness.

Use of Surfactants in Pasta-Manufacturing

The first use of natural surfactant, soybean lecithin, was made by Winston and Jacobs (9, 10) in 1947. They added 0.5% level of soybean lecithin in the processing of spaghetti and observed the effect of lecithin in the stage of processing (mixing, kneading, extruding, drying, and packing) on color retention and mechanical strength. They reported that lecithin could be added to pasta products by means of flour-lecithin premix. The finished lecithinized spaghetti presented a better appearance due to its greater degree of brightness, uniformity, and luminous reflectance; but produced a slight reduction in mechanical strength. Also the cooking quality was slightly, but definitely improved. The addition of lecithin reduced the degree of disintegration and yielded a product with a slightly greater increase in cooked volume and weight. Organoleptic test showed more people favored the lecithinized spaghetti due to a slight reduction in doughy taste and better appearance. The presence lecithin in cooked spaghetti inhibited syneresis and impeded undersirable changes during storage. It also maintained cooked products in a more appealing and appetizing state, especially suggesting its possible benefit in canned and cooked pasta products.

A similar observation was reported by Winston (11), using distilled monoglycerides. He found that pasta products containing 1.2% distilled monoglycerides had a superior cooking quality and produced a canned spaghetti with significant improvements in texture, firmness, and stickiness and showed more uniform cling for sauce.

In spite of the many intensive studies on improving cooking quality of pasta products, stickiness and softening problems still exist.

There is a dearth of research on noodles found in the literature. The term macaroni and/or pasta is applied to a variety of products. Macaroni products, as found in the literature, refer to macaroni, spaghetti, noodles, and specialty goods. Spaghetti is referred to as a "long goods" and noodles a "short goods".

The standards for enriched noodles and noodle variations are set forth in the Federal Register Part 16, 1964. Many variations are allowed, but must be set forth in the label on the package.

Holliger (28) believes that gluten quality is more important than gluten quantity in the production of noodles. Gluten quality can be altered greatly by heat conditioning in a moist atmosphere. However, extreme differences in gluten quality in wheats do not always lead to extreme differences in the cooking behavior of the resulting noodles. He demonstrated that acceptable noodles can be made from hard red spring and hard red winter as well as from soft red winter and soft spring wheats. No reference was made to making noodles from white club wheats. This worker based his results on the assumption that the gluten qualities (extensibility and strength) behave similarly with both soft and hard wheats.

MATERIALS

Flours Soft wheat flour (unbleached and unenriched), defatted soy flour (Nutrisoy), full-fat soy flour (Nutrisoy 220), soy protein isolate (SUPRO-610, edible isolated soy), and extruded whole soybeans were used. Soft wheat flour was obtained from Lyon & Greenleaf Company, Inc., Ligonier, Indiana; defatted and full-fat soy flours from Archer-Daniels-Midland Company, Decatur, Illinois: and soy protein isolate from Ralston Purina Company, Saint Louis, Missouri. Extruded whole soybean was prepared by Koehring Company, Des Moines, Iowa, and milled in Kansas State University's experimental mill. It was ground by a stone mill and sifted through 20W. Table 1 shows the compositions of soft wheat flour and various soy products.

TABLE 1. PROXIMATE ANALYSES OF PRODUCTS

Flours	Flour composition % Moisture	% Protein[b]	% Ash	% Fat
Wheat	12.4	9.6	0.41	-
Defatted soy	5.3	53.5	5.9	1.5
Full-fat soy	7.3	41.1	4.4	21.9
Soy protein isolate	7.0	86.1	3.5	0.2
Extruded soy meal	7.6	36.2	4.3	19.1

[b] N X 5.7 for wheat flour and N X 6.25 for soy products

Surfactants Sodium stearoyl-2-lactylate (SSL) and ethoxylated monoglyceride (EMG) were obtained from the C. J. Patterson Company, Kansas City, Missouri. Polyoxyethylene sorbitan monostearate (polysorbate 60) was produced by the Atlas Chemical Industries, Inc., Wilmington, Deleware. Glycerol monostearate (GMS) was a purified product manufactured by the Fisher Scientific Company, Fair Lawn, New Jersey. Sucrose monopalmitate (SMP), sucrose mono- and distearates (SMDS), sucrose distearate (SDS) were obtained from Dai-Nippon Sugar Manufacturing Company, Ltd., Tokyo, Japan. Sucrose tallowate (ST) was supplied by the Colonial Sugars Company, Gramercy, Louisiana. Monoglyceride (Myverol, MG) was a distilled product made by Distillation Products Industries, Division of Eastman Kodak Company, Rochester, New York.

Unless otherwise stated, soy products were used at the 18% level of replacement of wheat flour and 1.5% levels of surfactants and salt were added to wheat flour based on flour weight.

Salt Sodium chloride (analytical grade) used was purchased from Mallinckrodt Chemical Works, Saint Louis, Missouri.

METHODS

Visco-amylograph Basically, AACC Method (35) was used. Visco-amylogram was made on a Brabender visco-amylograph, Type VA-V, 700 cm. g. sensitivity cartridge at 75 r.p.m. For wheat flour control suspension, 60 g. of wheat flour (14% M.B.) were suspended in distilled water and made up to 500 ml. The slurry was then transferred to the cup of the Brabender Amylograph and heated and cooled at a rate of 1.5°C. per minute. The flour suspension was heated from 30°C. to 95°C., maintained at that temperature for an hour, then cooled to 50°C. and held for an hour. With those suspensions having high pasting viscosities, the recorder went off the chart. In such cases, additional weight was hung to the arm of the pen to keep the recorder on the chart.

Preparation of sample Rollecta-64 noodle machine (Torino, Italy) was used to prepare noodles. Wheat flour noodles, used as control, were made from 100% soft wheat flour and water only. Fortified noodles were made by replacing wheat flour with 18% soy products. Wheat flour and wheat-defatted soy blend noodles containing salt were also made.

The dough absorption was 35.5% for 100% wheat flour control noodles. Water absorption was adjusted to optimum for proper dough development, depending on the inclusion of soy products, surfactants, and salt. For control noodles, 200 g. sample of wheat flour were mixed in a Hobart N-50 mixer equipped with bowl and paddle for 2½ min. at speed 1, then scraped the bowl and paddle, and mixed another 2 min. at speed 2. When wheat flour contained soy products or surfactants (except EMG and polysorbate 60), ingredients were blended for 45 sec. in the mixer before water was added. Incorporation of EMG, plysorbate 60, and salt was done by dissolving in water.

The dough was passed between the smooth rollers, doubling it at every passage, until it became homogeneous and properly kneaded (i.e., 10 times), and thickened (1 mm. in thickness), then cut into strips 6 mm. wide and about 5 cm. long. The noodles were dried overnight at room temperature and stored in plastic bags.

Cooking of noodles Cooking was conducted in a steam bath maintained at 101°C. 250 ml. of distilled water were added to the lipless, tall form 600 ml. beakers. The beakers covered with watch glasses were placed in the bath and allowed to remain till the temperature reached 95-96°C.

For amylose determination, 5 g. of noodles were put into a beaker, and stirred till all pieces were separated and cooked for 7, 14, and 21 min. The cooking water was drained through 40 mesh (per inch) nylon screen. Drainings were collected in the lipless, tall form 500 ml. beakers and covered with watch glasses and cooled to room temperature before amylose was determined.

For residue determination, 10 g. of samples were used and cooked for 30 min. and the cooked noodles were drained in a Buchner funnel without suction for 10 min.

DETERMINATIONS

Amylose determination The procedure of McCready and Hassid (36) was used, with modification. A 1 ml. aliquot of cooking solution was combined with 5 ml. of 1.0N sodium hydroxide. After standing at room temperature for 30 min. with occasional shaking, the solution was brought to pH approximately 4 with 0.5N hydrochloric acid and made up to 100 ml. volume, including the addition of 1 ml. iodine reagent (0.2% I_2; 2.0% KI). The resulting blue color was read at 650 nm., using the Beckman DU Spectrophotometer. Amylose content from two replications of each sample was determined and reported as the mean absorbance.

Residue determination Residue of extracted solids in the cooking water was determined by AACC Method (37). The drainings from the cooked noodles were collected in tared 250 ml. beakers. The cooking solution was evaporated to dryness in 100°C. air oven and then dried at 130°C. for 1 hr. and weighed. The amount of residue was reported in grams from two replications of different samples. In the presence of salt, a correction for residue of salt was made by ashing an aliquot of the cooking water. Chloride content of cooking water was determined by AACC Method (38).

Soluble protein determination After determination of amylose, the cooking water was freeze-dried. The freeze-dried solids were stored at room temperature in a desiccator. The amount of soluble protein in the cooking water at different cooking times was determined by the micro-Kjeldahl method (39). Extractable protein from two replicated samples was expressed as a percentage of total nitrogen.

Organoleptic test The noodles were evaluated organoleptically by the method described by Perjam and Pilgrim (40) for appearance, flavor, texture, and acceptability. The taste panel members consisted of five trained graduate students and staff, four of the Asians. The samples were randomized, coded, and cooked for 10 min. on same days of consideration by the taste panels. Codes for each sample were visible to each panel member by marking the plates on which the samples were presented. The taste panel members were asked to judge the products by their preference. The characteristics and acceptability of the noodles were evaluated using the key given in Table 2. Two replications of each test were done on different days.

TABLE 2

Key for Panel Evaluation

Factors:		Descriptive terms						Comments
Appearance	(4)	Uniform, no deformed pieces						
	(3)	Slight deformed pieces						
	(2)	Uneven shape, some split pieces						
	(1)	Badly split						
Flavor	(4)	Bland, wheaty flavor						
	(3)	Bland						
	(2)	Starchy or pasty						
	(1)	Off-flavors, e.g., musty, beany, etc.						
Texture	(4)	Firm (slightly chewy)						
	(3)	Tender (not chewy)						
	(2)	Soft or mushy						
	(1)	Tough (rubbery)						
Acceptability (overall)								

SCORE KEY FOR ACCEPTABILITY

5; Highly acceptable
4; Moderately acceptable
3; Acceptable
2; Moderately unacceptable
1; Highly unacceptable

RESULTS AND DISCUSSION

Visco-amylograph Studies

Characteristic visco-amylograms obtained from wheat flour and wheat-soy blend suspensions with or without different surfactants are presented in Figs. 1 and 2. Tables 3-6 summarize the data as affected by surfactants, soy products,or salt on the visco-amylogram.

Pasting temperature. Pasting temperature of wheat flour control suspension was 60.5°C. The surfactants caused the pasting temperature to range from 60.5° to 66.5°C. When MG was added to the wheat flour suspension, the least increase in the pasting temperature was observed but largest increase in the pasting temperature was obtained with the addition of ST. Addition of a group of EMG, GMS, SDS and a group of SMP, SMDS and of a group of SSL, polysorbate 60 to the wheat flour suspensions showed the same effect on the pasting temperature (Table 3).

Replacement of wheat flour with 18% soy products caused the pasting temperature to be 62°C. with defatted soy flour and soy protein isolate, to be 65°C with full-fat soy flour, and to be 63.5°C with extruded soy meal. When wheat-soy blend suspensions contained the surfactants, the pasting temperature was affected remarkably ranging from 62° to 85°C. Wheat-soy protein isolate suspensions had least influence on pasting temperature in the presence of surfactants. When wheat-defatted soy, wheat-full-fat soy, and wheat-extruded soy meal suspensions contained SSL, SMP, ST, and SMDS, the pasting temperature was very high ranging from 80.5° to 85°C. One exception was that the pasting temperature was 77°C with the use of SMDS in the wheat-extruded soy meal suspension. EMG, polysorbate 60, and SDS showed a

Fig. 1. visco-amylogram of wheat flour suspensions as affected by surfactants and/or defatted soy flour.

THIS BOOK CONTAINS NUMEROUS PAGES WITH DIAGRAMS THAT ARE CROOKED COMPARED TO THE REST OF THE INFORMATION ON THE PAGE.

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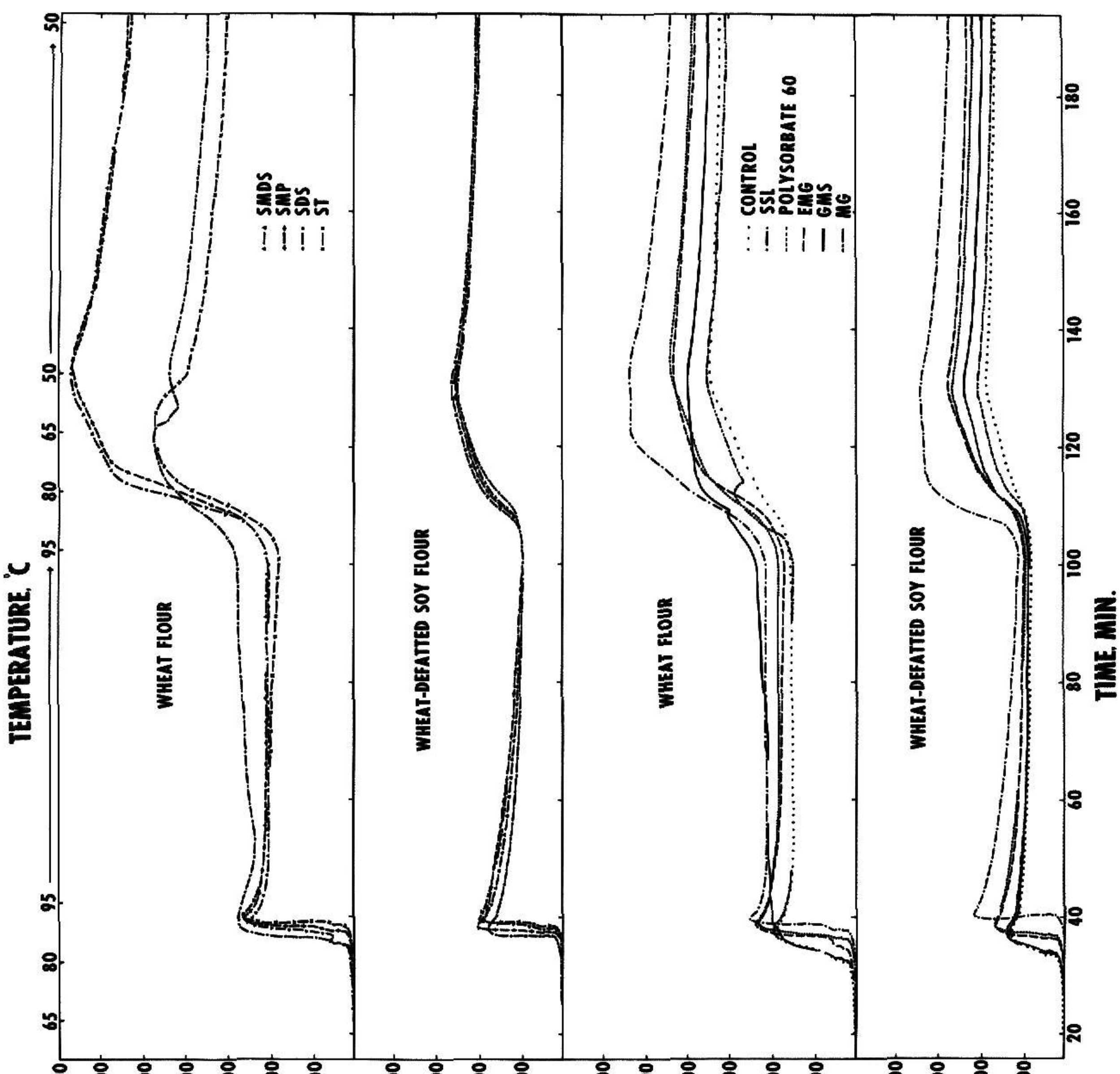

TEMPERATURE, °C
65
80
95
95
80
65
50
50
WHEAT FLOUR
WHEAT-DEFATTED SOY FLOUR
WHEAT FLOUR
WHEAT-DEFATTED SOY FLOUR
SMDS
SMP
SDS
ST
CONTROL
SSL
POLYSORBATE 60
EMG
GMS
MG
VISCOSITY, B.U.
1400
1200
1000
800
600
400
200
TIME, MIN.
20
40
60
80
100
120
140
160
180

Fig. 2. Visco-amylogram of wheat flour suspensions as affected by surfactants and/or soy products.

Correction: Wheat-isolate soy protein flour is wheat flour-soy protein isolate.

Wheat-coarse ground whole soy is wheat flour-extruded soy meal.

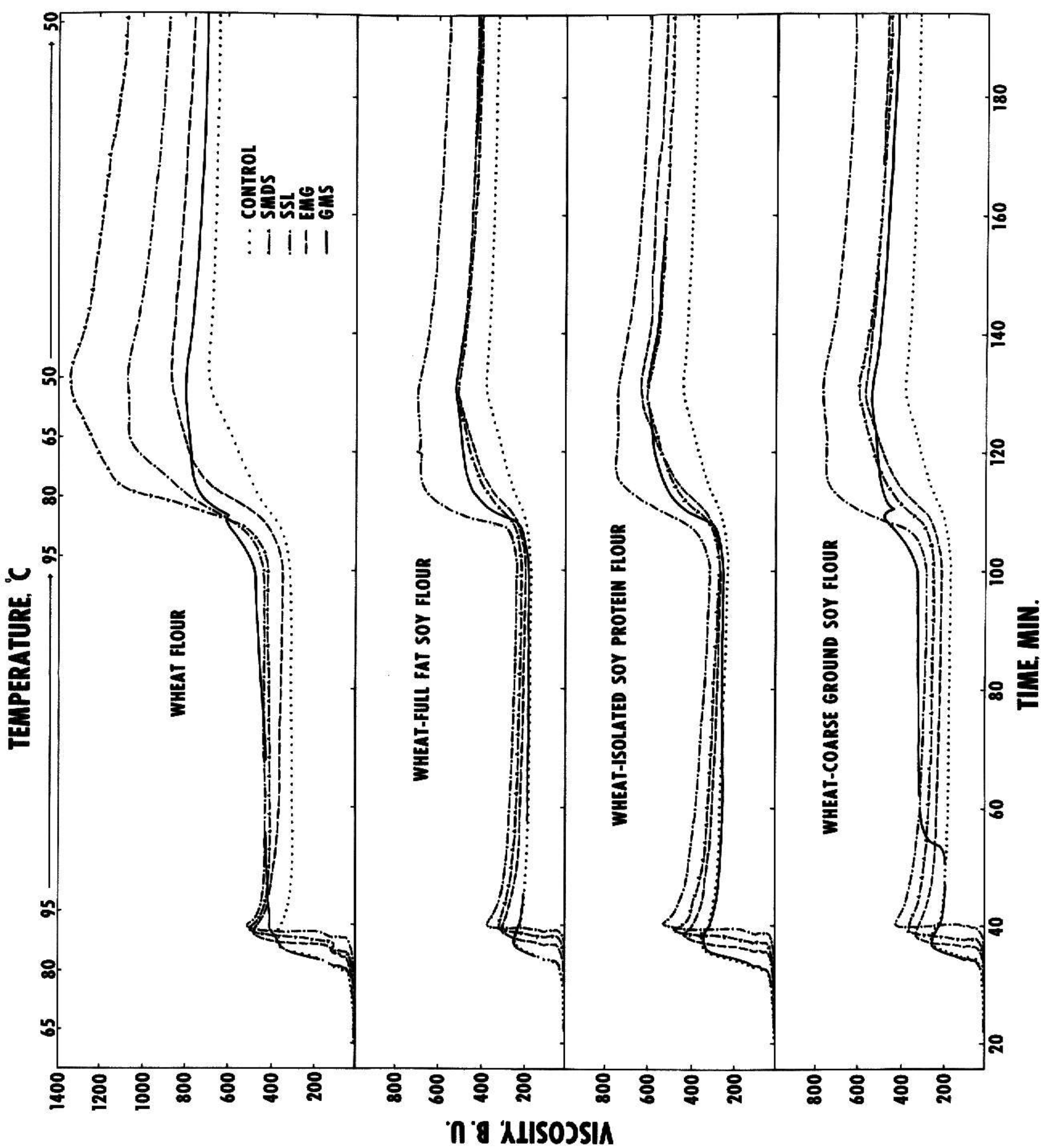

TEMPERATURE, °C
65
80
95
95
80
65
50
50
VISCOSITY, B. U.
1400
1200
1000
800
600
400
200
WHEAT FLOUR
WHEAT-FULL FAT SOY FLOUR
WHEAT-ISOLATED SOY PROTEIN FLOUR
WHEAT-COARSE GROUND SOY FLOUR
CONTROL
SMDS
SSL
EMG
GMS
20
40
60
80
100
120
140
160
180
TIME, MIN.

TABLE 3

Effects of Surfactants and/or Defatted Soy Flour on Pasting Properties of Wheat Flour Suspensions

Surfactants	Wheat Flour						82% Wheat Flour + 18% Defatted Soy Flour					
		Peak		Viscosity				Peak		Viscosity		
	Pasting temp. °C	Vis. B.U.	Temp. °C	1 hr. Holding at 95°C B.U.	Cooled to 50°C B.U.	1 hr Holding at 50°C B.U.	Pasting temp. °C	Vis. B.U.	Temp. °C	1 hr. Holding at 95°C B.U.	Cooled to 50°C B.U.	1 hr Holding at 50°C B.U.
Control[a]	60.5	388	94	325	675	650	62	270	92	170	375	340
SSL	65	515	95(1½min.)	440	1075	890	85	443	95(2min.)	235	690	550
EMG	62	485	95(½min.)	355	865	760	75.5	342	95	200	550	465
GMS	62	410	95(1min.)	478	800	700	66	270	91	175	470	390
MG	61	400	93.5	310	690	620	63.5	290	92	175	410	350
Polysorbate 60	65	470	95(½min.)	378	870	780	71	345	95	195	535	440
SMP	63.5	528	95(1½min.)	418	1335	1080	80.5	420	95	200	510	410
SMDS	63.5	500	95(1min.)	420	1338	1060	80.5	383	95(1min.)	195	503	408
SDS	62	553	95(½min.)	555	870	700	68	365	94.5	198	505	418
ST	66.5	535	95(1½min.)	370	850	615	82	405	95(1min.)	200	525	415

[a]Flour suspensions without surfactant

TABLE 4

Effects of Surfactants and/or Full-Fat Soy Flour on Pasting Properties of Wheat Flour Suspensions

	Wheat Flour						82% Wheat Flour + 18% Full-Fat Soy Flour					
		Peak		Viscosity				Peak		Viscosity		
Surfactants	Pasting temp. °C	Vis. B.U.	Temp. °C	1 hr. Holding at 95°C B.U.	Cooled to 50°C B.U.	1 hr. Holding at 50°C B.U.	Pasting temp. °C	Vis. B.U.	Temp. °C	1 hr. Holding at 95°C B.U.	Cooled to 50°C B.U.	1 hr. Holding at 50°C B.U.
Control[a]	60.5	388	94	325	675	650	65	245	91.5	170	370	335
SSL	65	515	95(1½min.)	440	1075	890	85	375	95(1½min.)	240	700	555
EMG	62	485	95(½min.)	355	865	760	75.5	308	95	200	500	425
GMS	62	410	95(1min.)	478	800	700	63.5	250	90.5	180	518	420
SMDS	63.5	500	95(1min.)	420	1338	1060	81.5	325	95(1min.)	220	510	410

[a]Flour suspensions without surfactant

TABLE 5

Effects of Surfactants and/or Soy Products on Pasting Properties of Wheat Flour Suspensions

Surfactants	82% Wheat Flour + 18% Soy Protein Isolate						82% Wheat Flour + 18% Extruded Soy Meal					
		Peak		Viscosity				Peak		Viscosity		
	Pasting temp. °C	Vis. B.U.	Temp. °C	1 hr. Holding at 95°C B.U.	Cooled to 50°C B.U.	1 hr. Holding at 50°C B.U.	Pasting temp. °C	Vis. B.U.	Temp. °C	1 hr. Holding at 95°C B.U.	Cooled to 50°C B.U.	1 hr. Holding at 50°C B.U.
Control[a]	62	360	94	234	430	380	63.5	260	91.5	175	380	338
SSL	69.5	535	95(2min.)	320	750	600	83	435	95(2min.)	290	770	630
EMG	63.5	435	95	270	630	525	75.5	340	95	220	565	480
GMS	62	305	92	255	603	490	64	260	91.5	330	545	440
SMDS	63.5	480	95(1min.)	270	600	490	77	370	95(1min.)	255	590	465

[a]Flour suspensions without surfactant

TABLE 6

Effect of Salt on Pasting Properties of Wheat Flour Suspensions With or Without Surfactants and Defatted Soy Flour

	Wheat Flour						82% Wheat Flour + 18% Defatted Soy Flour					
		Peak		Viscosity				Peak		Viscosity		
Surfactants	Pasting temp. °C	Vis. B.U.	Temp. °C	1 hr. Holding at 95°C B.U.	Cooled to 50°C B.U.	1 hr. Hold-ing at 50°C B.U.	Pasting temp. °C	Vis. B.U.	Temp. °C	1 hr. Holding at 95°C B.U.	Cooled to 50°C B.U.	1 hr. Hold-ing at 50°C B.U.
Control[a]	63.5	445	94	345	710	675	65	298	92	178	390	355
SSL	65	530	95(3min.)	425	955	810	88	380	95(3½min.)	218	628	503
EMG	62	533	95(½min.)	363	950	825	77	338	95	190	510	435
GMS	63.5	485	95(1min.)	503	825	718	65	348	95	295	440	360
SMDS	65	525	95(1½min.)	398	1240	790	70.5	373	95(½min.)	190	495	398

[a]Flour + salt suspensions without surfactant

moderately high pasting temperature ranging between 68° and 75.5°C. GMS and MG had a slightly higher pasting temperature than wheat-soy blend control suspensions.

The pasting temperatures of wheat flour and wheat-defatted soy flour suspensions containing salt were 63.5°C and 65°C, respectively. The presence of salt increased the pasting temperature in wheat flur susupensions containing GMS and SMDS, but the pasting temperature with SSL and EMG was equal to the pasting temperature of wheat flour suspensions without salt. The pasting temperature was increased in wheat-defatted soy flour suspensions containing salt with SSL and EMG, but decreased with GMS and SMDS, compared to the suspensions in the absence of salt.

Appreciable granule swelling must occur before the viscosity was sufficiently high to be recorded by the Brabender amylograph. Investigations of the action of monoglyceride (41) and polyoxyethylene monostearate (42-45) have shown that both surfactants inhibited the swelling of starch granules and caused starch gels to be tender and weak. From the observed results, it is indicated that the presence of surfactants and soy products restricted the granule swelling in the wheat flour suspensions. In general, the most pronounced restriction in granule swelling was found with SSL, ST, SMDS, and SMP. The moderate restriction of swelling was found with EMG, polysorbate 60, and SMDS, whereas MG and GMS had only slight effect. Of the soy products tested, the full-fat soy flour inhibited the granule swelling more than any other soy products. Salt had no consistant effect on the granule swelling in the flour suspensions.

Peak temperature. For wheat flour control suspension, peak temperature was 94°C. When surfactants were added to wheat flour suspensions, except for MG, temperatures peaked within an hour and held at 95°C (Table 3).

Replacement of soy protein isolate for wheat flour caused no change in peak temperature. Defatted soy flour, full-fat soy flour, and extruded soy meal replacement decreased the peak temperature from 94°C to approximately 92°C. When all of the wheat-soy blend suspensions contained EMG, GMS, MG, polysorbate 60, SMP, SDS, and ST, the peak temperature decreased; but no change in the peak temperature was found with SMDS. SSL showed the same peak temperature with the replacement of full-fat soy flour, compared to the peak temperature of wheat flour suspension; but showed 0.5°C increase with defatted soy flour, soy protein isolate, and extruded soy meal replacements.

Peak temperature was not affected by salt in the wheat flour and in the wheat-defatted soy flour suspensions which had the peak temperature 94°C and 92°C, respectively. Salt increased the peak temperature slightly in the wheat flour suspensions with SSL and SMDS. A slight increase of the peak temperature was also shown in the wheat-defatted soy flour suspensions containing SSL and GMS.

Accordingly, it is evident that the presence of surfactants, soy products, and salt changed the peak temperature. Addition of surfactants to the wheat flour suspensions increased the peak temperature except for MG. With wheat-soy blend suspensions the peak temperature was reduced except for soy protein isolate which had no effect on the peak temperature. The presence of both surfactants and soy products tended to decrease the peak temperature except for SSL, but salt slightly increased the peak temperature in the wheat flour and wheat-soy blend suspensions.

By measurement of the loss of birefringence, D'Appolonia (46) and Ganz (47) reported that the inhibition of starch hydration resulted in the higher pasting and peak temperatures. The peak temperature in the present investigation suggests that the surfactants caused the starch granule to remain intact longer before fragmentation occurs.

Hot paste viscosity. Most granular starches thin down during 1 hr. cooking period at 95°C, due to the progressive fragmentation and solubilization of the swollen granules. This effect is particularly evident in the great difference between the initial and final viscosities at 95°C.

The difference between the initial and the final viscosities at 95°C was 63 B.U. for wheat flour control suspension. With the exception of GMS and SDS, as surfactants were added to the wheat flour suspensions, the differences between the initial and the final viscosities ranged from 74 to 165 B.U. This indicates that a relative thinning of suspensions on cooking was greater with surfactants than with control. The great differences, with EMG (130 B.U.) and ST (165 B.U.), showed a marked thinning on cooking. This occurred to a lesser degree with SSL, MG, polysorbate 60, SMP, and SMDS. No thinning during cooking was observed with GMS and SDS (Table 3).

When wheat flour was replaced with soy products, the differences ranged from 75 to 125 B.U. (Table 3-5). Full-fat soy flour replacement showed the least thinning on cooking, but soy protein isolate showed the most effect on thinning. When wheat-soy blend suspensions contained surfactants, there was a greater thinning, compared to the wheat flour suspensions containing surfactants. With incorporation of soy products and surfactants, the range of differences was from 50 to 210 B.U. GMS and SDS showed also relatively less thinning in the wheat-soy blend suspensions except that GMS caused increased viscosity on cooking in the extruded soy meal suspension.

The addition of salt to the wheat flour and to the wheat-defatted soy flour suspensions showed minor change on cooking. As surfactants and salt were added to the wheat flour suspensions, there was a tendency to increase the thinning during cooking except for SMDS; but added salt and surfactants in the wheat-defatted soy flour suspensions tended to increase the cooking stability.

The drop in viscosity from a maximum value to that obtained after 1 hr. holding period at 95°C indicates the stability of the paste would breakdown on cooking. Of the surfactants investigated, results show that the increase of stability during cooking occurred only with GMS and almost no change in stability was shown with SDS. However, the flour suspensions including the surfactants, soy products, or the presence of both generally decreased the stability on cooking. Salt decreased the stability in wheat flour suspensions containing surfactants but increased the stability in the wheat-defatted soy flour suspensions containing surfactants.

Set-back on cooling. The extent of increase in viscosity on cooling to 50°C reflects the set-back of starch products. For wheat flour control suspension, the increase in viscosity was 350 B.U. during cooling. The increase in viscosity on cooling ranged between 315 and 918 B.U., when surfactants were added to the wheat flour suspensions. Of the nine surfactants used, the wheat flour suspensions containing GMS and SDS showed less tendency of set-back than the wheat flour control suspension. SMP and SMDS showed the largest increase in viscosities.

With the replacement of soy products for the wheat flour, the set-back were reduced so the viscosity increases were approximately 200 B.U. The increase in viscosity was markedly inhibited by the presence of surfactants in the wheat-soy blend suspensions. The range was from 215 to 480 B.U. Especially, SMDS and SMP showed the most pronounced set-back decrease in wheat-soy blend suspensions.

With salt, a slight increase in set-back was found in the wheat flour suspensions. Viscosity was slightly decreased with SSL and greatly decreased with SMDS, whereas little effect was shown with GMS and EMG. Salt influenced the viscosity in wheat-soy blend suspensions slightly. The presence of salt in wheat-defatted soy flour suspension containing GMS decreased the viscosity considerably.

Consequently, with the exception of GMS and SDS, the presence of surfactants showed the increase of set-back during cooling in wheat flour suspensions. However, the presence of soy products in the wheat flour suspensions tended to decrease the set-back with or without surfactants. To a lesser extent, salt had a tendency to decrease set-back in wheat flour and wheat-defatted soy flour suspensions with or without surfactants.

In summary of data of the visco-amylogram studies, it is suggested that the presence of surfactants had three primary effects on the pasting properties of flour suspensions. The first effect was to restrict swelling of starch granules. The second effect was to increase granule integrity. The third effect was to change the degree of set-back on cooling. When compared to the surfactants, soy products and salt had little influence on the first two but had a marked influence on the latter. With surfactants, it has been generally recognized that these effects are essentially due to the formation of complex between the fatty adjuncts and the linear fraction of the starch. Gray and Schoch (48) reported that surfactants which complex strongly with linear fraction restricted the swelling and solubilization of corn, potato, and waxy sorghum starches over the pasting range of 60°-95°C.

Results of the heating-holding-cooling cycle on flour pasting properties may relate to the possible change that can occur during cooking of noodles.

However, visco-amylograph studies showed no correlation with the amount of soluble starch leached out during cooking as shown by determination of amylose in the cooking water, even though surfactants restricted the swelling and solubilization of starch granules. These observations would indicate that the extent of granule swelling and solubilization has a major influence on pasting properties, but it seems that the amount of amylose in the cooking water was not directly related to the restricted swelling and solubilization of starch as measured with the visco-amylograph.

Similar observations have been made on bread. Effect of surfactants on crumb firmness in bread (49) and on the Brabender amylograph curves of corn starch pastes (50) did not appear to be directly related to their complex formation with amylose under conditions of these experiments.

As a plausible explanation, it is indicated that surfactants used may differ in their abilities to form complexes under present conditions in wheat flour and wheat-soy blend pastes or in noodles.

Release of Soluble Starch in the Cooking

The well-known starch-iodine reaction is the result of a helix formation around I_2, to produce a blue color. Surfactants also have the ability of combining with the amylose component of the starch molecules to form a complex, an insoluble compound. The formation of such complexes with amylose fraction of starch has been demonstrated quite conclusively by its interference with the affinity of the amylose for iodine (43, 45, 51). An explanation proposed for the effect of surfactants or fatty acids on iodine affinity rests on the structure of the complexes involved. Hanes (52) postulated a helical configuration for the starch-iodine complex. Later studies of Rundle and his co-workers (53-58) supported the above hypothesis.

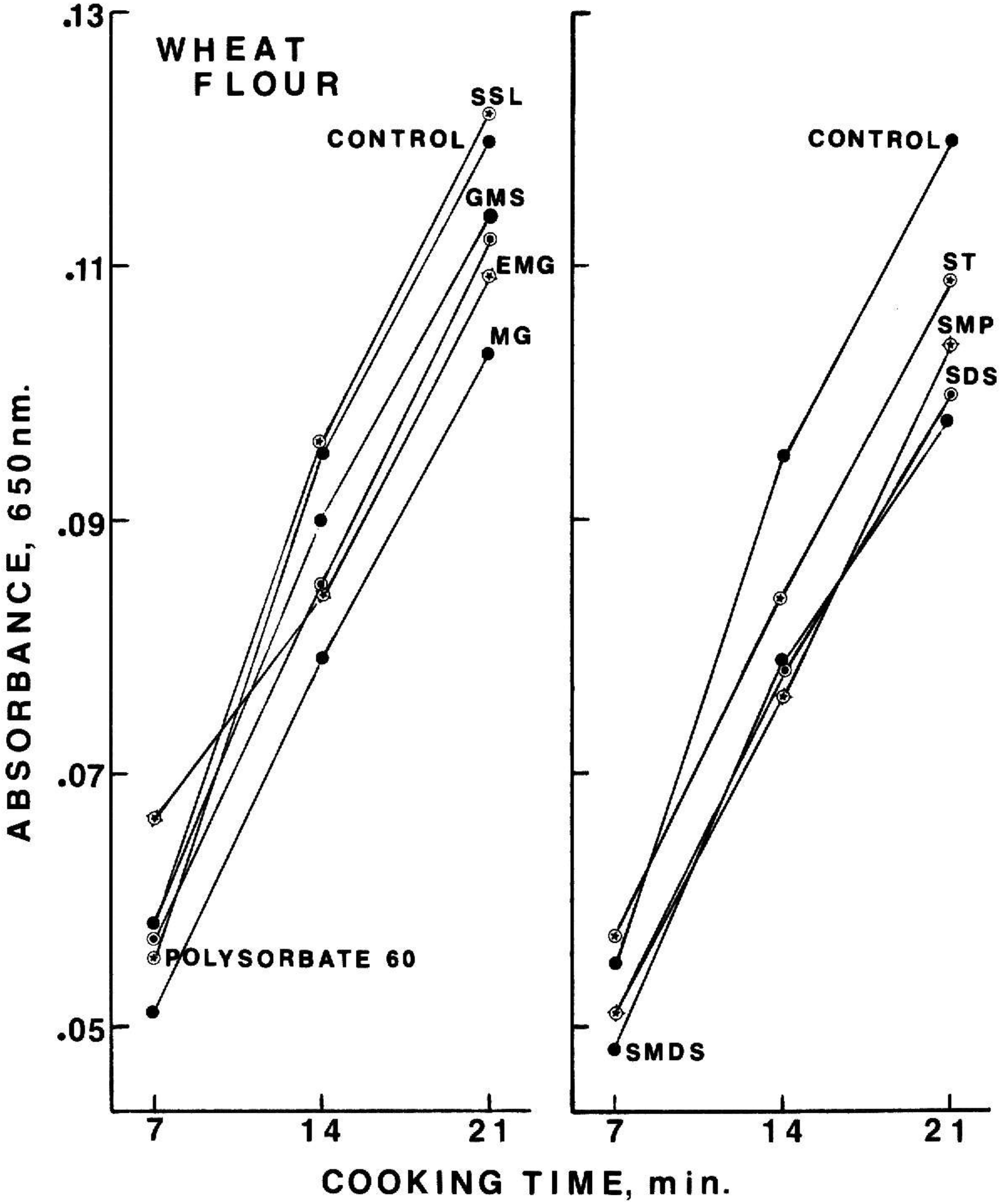


Fig. 3. Comparison of the released amylose of wheat flour noodles due to the effect of surfactants at various cooking times.

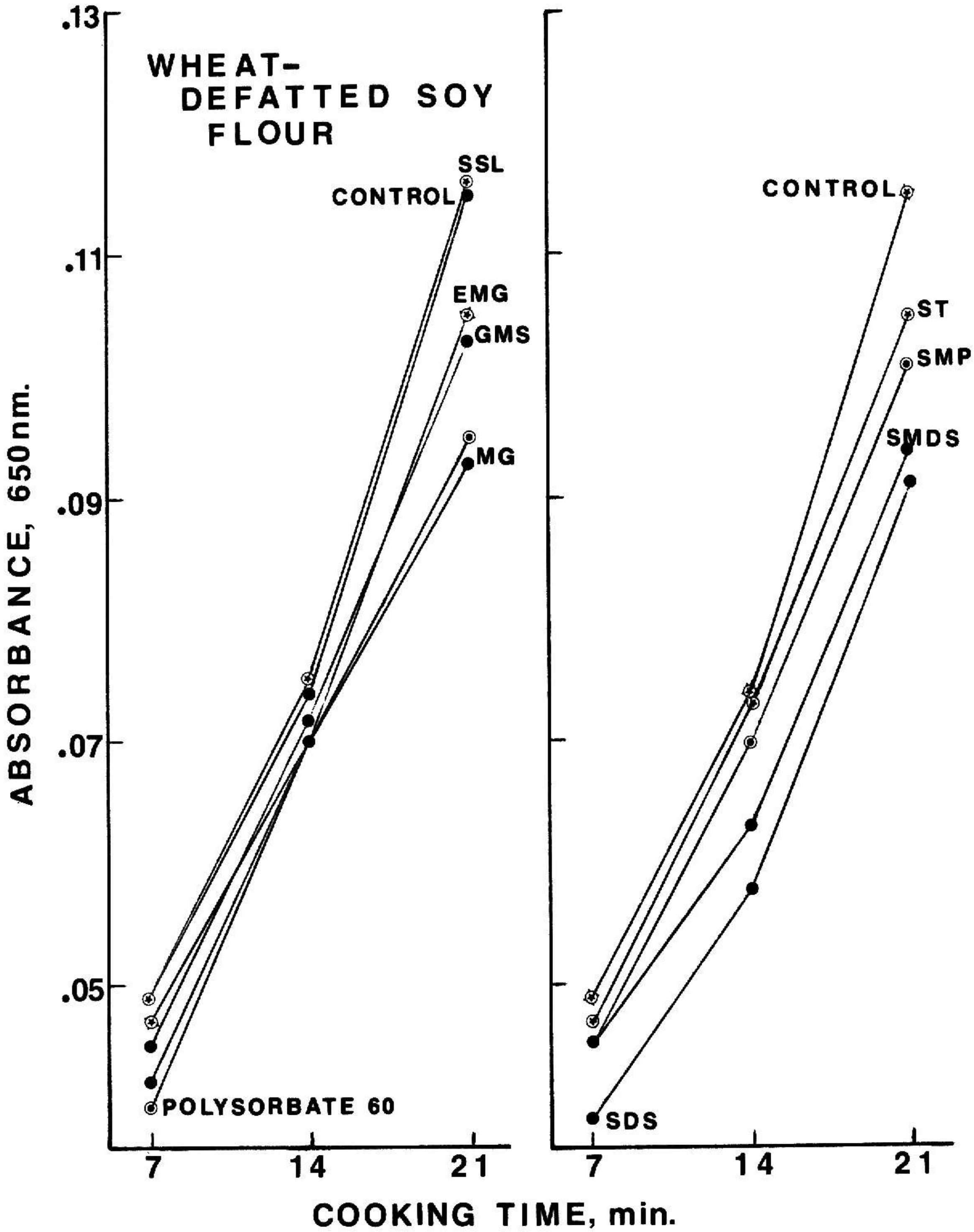


Fig. 4. Comparison of the released amylose of wheat-defatted soy blend noodles due to the effect of surfactants at various cooking times.

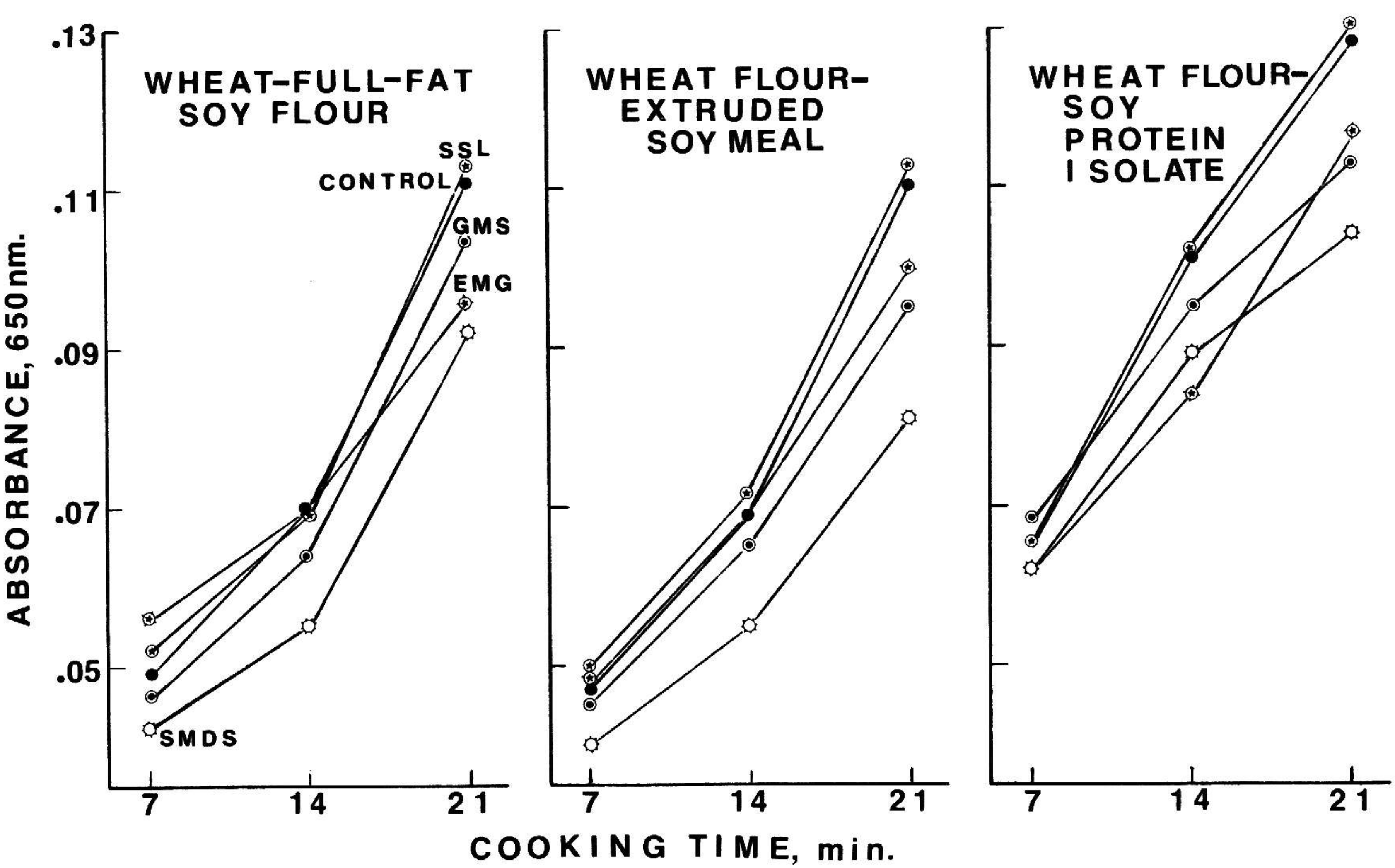


Fig. 5. Comparison of the released amylose of wheat-soy blend noodles due to the effect of surfactants at various cooking times.

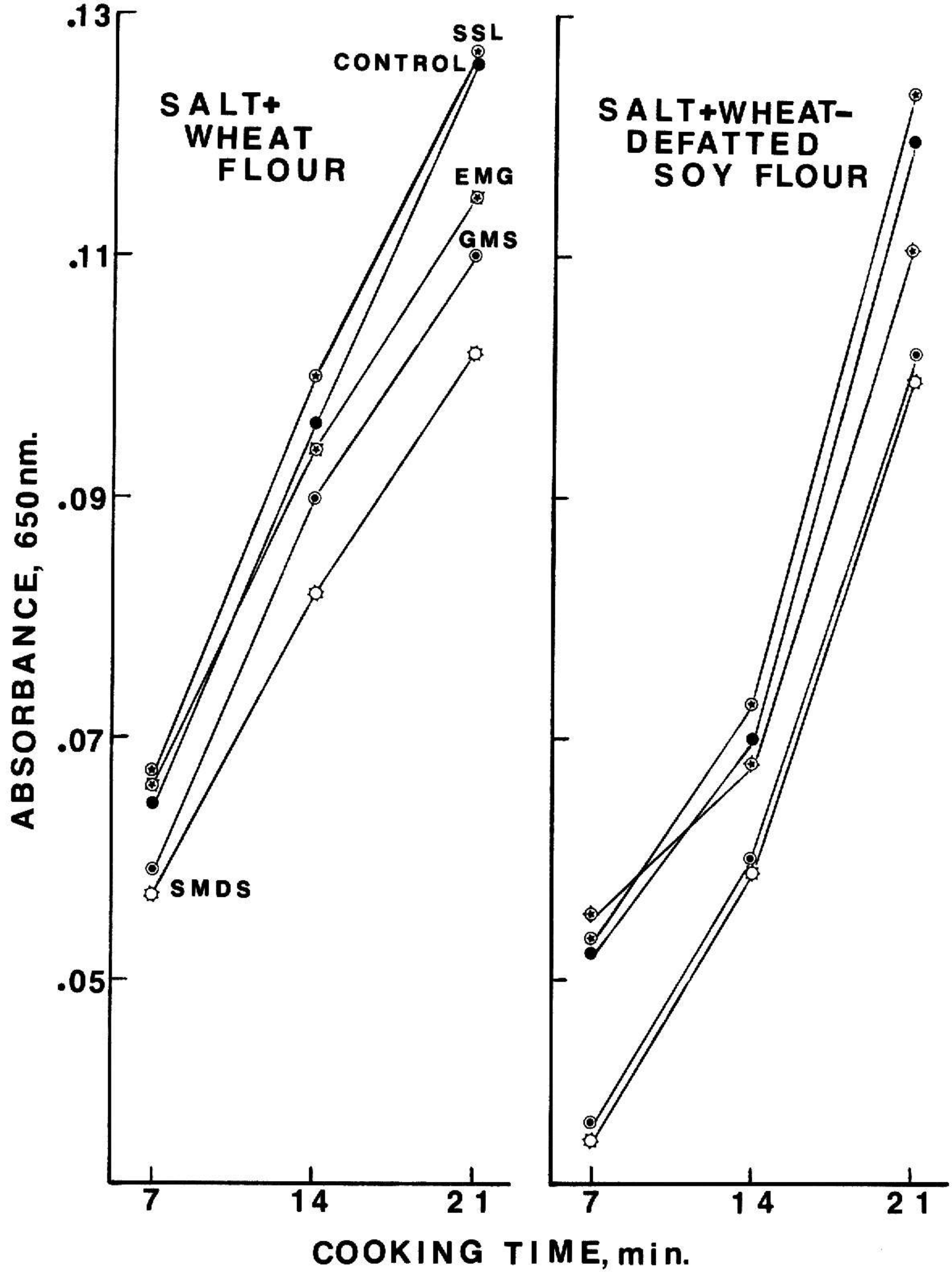


Fig. 6. Comparison of the released amylose of wheat flour and wheat-defatted soy blend noodles with or without surfactants due to the effect of salt at various cooking times.

They suggested that the iodine molecules were oriented in a linear arrangement enclosed within and parallel to the axis of an amylose helix. Such helix complexes are called inclusion compounds or clathrates. Schoch (15) reported that starch clathrates were insoluble in water. Mikus et al. (59) used this phenomena, the intense blue color resulting from the iodine clathrate (or lack of it), as an analytical tool to determine whether the starch has been previously complexes or not.

The lack of reaction was used in the present study to determine the degree to which a surfactant complexed with amylose, thus reducing stickiness and pastiness of the noodles. The effects of surfactants, soy products, and salt on the release of amylose into the cooking water are shown in Figs. 3-6. As shown in these figures, the amylose content of the cooking water increased with increasing cooking time.

Effect of surfactants. Generally, surfactants used were more effective on longer than on shorter cooking time. With the addition of surfactants to the wheat flour dough, less amount of amylose was leached out during cooking except SSL which had no effect, and EMG and ST caused more amylose to be leached out at 7 min. of cooking time. When SMDS, SDS, MG, and SMP were added to the wheat flour doughs, they showed considerable ability for combining with amylose. In contrast, SSL showed little helix formation with amylose. With SSL, more amylose was found in the cooking water. This could be due to the fact that mere monomolecular layers were adsorbed on starch granules which reduced the swelling and solubilization as shown by visco-amylograph studies. SSL, however, would seem to act as a barrier to moisture loss from the starch granules, indicating no possible amylose-binding capacities. This decrease of liberated amylose in the cooking water was made greater by the addition of GMS, polysorbate 60, EMG or ST, SMP, MG, SDS, and SMDS to the wheat flour doughs, in that order at 21 min. cooking time (Fig. 3).

Effect of soy products. As defatted soy flour, full-fat soy flour, and extruded soy meal replaced the wheat flour, the amylose content of the wheat-soy blend noodles decreased in the cooking water. On the other hand, the amount of amylose of wheat-soy protein isolate noodles increased in the cooking water. Since soy products contain no starch and gluten, replacement with soy products dilutes the starch and gluten in wheat flour noodles. However, this improvement with soy products could be attributed to the presence of lecithin, which is one of natural surfactants, in the crude fat of soy products. When protein content was increased by substitution of soy protein isolate, the cooking quality of noodles was impaired. This could be due to the excessive removal of fat during soy protein isolate processing. Among the soy products investigated, full-fat soy flour and extruded soy meal showed a little better cooking quality than defatted soy flour from the point of view of the released amylose in the cooking water.

Matsu et al. (33) reported that fortified spaghetti obtained from rapeseed flour and fish protein concentrate impaired the cooking quality, resulting in soft and nonelastic products. This impairment of cooking quality could be caused by the release of amylose during cooking, thus showing a correlation between softening of noodles and liberating amylose in the cooking.

Effect of surfactants and soy products. With the single exception of SSL, when surfactants were added to the wheat-soy blend doughs, the amount of amylose leached into the cooking water was decreased. Addition of surfactants to the wheat-defatted soy doughs decreased amylose in the cooking water, followed by decreasing in order of EMG or ST, GMS, SMP, polysorbate 60, SMDS, MG, and SDS. Addition of EMG to the wheat-full-fat soy flour and wheat-extruded soy meal doughs, and of GMS to the wheat-soy protein isolate dough increased the amylose in the cooking water at 7 min. cooking time. As SMDS was included in wheat-full-fat soy, wheat-extruded soy, and wheat-soy protein isolate doughs, the largest decrease of amylose was found in the cooking water (Fig. 5). When both soy products and surfactants were present with wheat flour, the changes in decreasing order of amylose in the cooking water were observed (Figs. 4-5). Also further decreases of amylose in the wheat-soy blend noodles containing surfactants were found except for wheat-soy protein isolate noodles. These observations could suggest that the simultaneous presence of surfactants and lecithin of soy products in wheat flour doughs could exert synergistic effects on the release of amylose.

Effect of salt. Generally, added salt increased the amylose content of cooking water, compared to the wheat flour doughs with or without surfactants and to the wheat-defatted soy doughs in the presence or absence of surfactants. Specially, when salt only or both salt and surfactants were present in the wheat-defatted soy doughs, considerable amount of amylose was leached out after 14 min. cooking time (Fig. 6). When wheat flour and wheat-defatted soy doughs contained salt and surfactants, a large decrease of amylose during cooking was obtained with SMDS, followed by decreasing in order of GMS and EMG.

Binnington et al. (17) studied the effect of addition of salt in the cooking water. They found that added salt exerted a marked softening effect during cooking. Their results could also be related to the amount of released amylose during cooking.

From the preceding discussions, it is noted that the change in amylose in the cooking water was due to the surfactants-amylose binding capacities. The present results clearly demonstrate that the use of surfactants in noodle manufacturing resulted in small losses of amylose in the cooking water, thus eliminating the characteristic stickiness and pastiness in the cooked products. Also, those earlier reports and the present observations support the generally recognized fact that the cooking of pasta products is closely related to the amylose leached out during cooking. As less amylose was found in the cooking water, considerable improvement in cooking quality could be expected; so the products are firmer, less sticky, more elastic.

Degree of Disintergration as Affected by Surfactants, Soy Products, or Salt on Cooking

Tables 7-9 show the means of residue values expressed in g., since pasta products of good quality possess a high degree of resistance during cooking.

The residue value from the wheat flour control noodles was 0.630 g. With the single exception of SSL, addition of surfactants to wheat flour doughs tended to reduce the disintegration at 30 min. cooking time. This exception with SSL might be due to the improper drying of samples. Checking and cracking occurred during drying and deformation also occurred during cooking in wheat flour noodles and in wheat-soy blend noodles containing SSL, in contrast to the noodles containing other surfactants. When the residue values were arranged in decreasing order, the release of amylose into the cooking water decreased also, except for polysorbate 60 and EMG. This variation could be due to the

TABLE 7

Effect of Surfactants and/or Defatted Soy Flour on the Residue Value of Noodles Made from Wheat Flour during Cooking[a]

Surfactant	Wheat flour g. residue	82% Wheat flour + 18% defatted soy flour g. residue
Control	0.630	0.898
SSL	0.648	0.908
EMG	0.604	0.868
GMS	0.612	0.863
MG	0.584	0.835
Polysorbate 60	0.618	0.876
SMP	0.587	0.860
SMDS	0.558	0.815
SDS	0.575	0.795
ST	0.609	0.865

[a]Cooking time, 30 min.

TABLE 8

Effect of Surfactants and/or Soy Products on the Residue Value of Noodles Made From Wheat Flour During Cooking[a].

Surfactant	82% wheat flour + 18% full-fat soy flour g. residue	82% wheat flour + 18% soy protein isolate g. residue	82% wheat flour + 18% extruded soy meal g. residue
Control	0.817	0.810	0.828
SSL	0.856	0.835	0.841
EMG	0.796	0.795	0.820
GMS	0.802	0.785	0.799
SMDS	0.775	0.702	0.716

[a]Cooking time, 30 min.

TABLE 9

Effect of Salt on the Residue Value of Noodles Made from Wheat Flour and Wheat-Defatted Soy Blend With or Without Surfactants During Cooking[a]

Surfactant	Wheat flour[b]	82% Wheat flour + 18% defatted soy flour[b]
	g. residue	g. residue
Control	0.732	0.953
SSL	0.749	0.994
EMG	0.712	0.945
GMS	0.692	0.928
SMDS	0.664	0.916

[a]Cooking time, 30 min.

[b]1.5% salt added.

brittleness of noodles containing these surfactants. When wheat flour noodles contained surfactants, the residue values in decreasing order were as follows: Polysorbate 60, GMS, ST, EMG, SMP, MG, SDS, and SMDS.

Noodles fortified with soy products increased the amount of extracted solids considerably during cooking. Fortified noodles obtained from defatted soy flour changed the residue value from 0.630 to 0.898 g. The residue values for wheat-full-fat-soy blend noodles, for wheat-extruded soy blend noodles, and for wheat-soy protein isolate blend noodles were 0.817 g., 0.828 g., and 0.810 g., respectively. Among the soy products used, defatted soy flour replacement showed the highest residue values and then extruded soy meal, and soy protein isolate in that order. This increase in residue value was caused by the soy products which contained a high amount of soluble carbohydrates and protein, and of ash. When noodles were made by including defatted soy flour and surfactants, SDS had the lowest residue value, followed by SMDS, MG, SMP, GMS, ST, EMG, polysorbate 60, and SSL. SMDS reduced residue values most as noodles were prepared from wheat-full-fat soy flour, wheat-extruded soy meal, and wheat-soy protein isolate (Table 8).

Recently, Wolf (60) reported the approximate compositions and yields of various forms of soybeans. There were no composition differences between full-fat and defatted soy flours except fat; but whole soybeans had more carbohydrates and oil than defatted soy flour.

The differences of residue values between wheat-defatted soy blend and wheat-full-fat soy blend noodles with or without surfactants could be due to the presence of more fat in full-fat soy flour than in defatted soy flour; so the less amounts of amylose and of soluble protein in the cooking water were found with wheat-full-fat soy blend noodles.

When comparing the residue values between wheat-full-fat soy blend and wheat-extruded soy blend noodles, the differences between them were small, although extruded soy meal contained the bran and hull. Lower residue value was obtained in wheat-full-fat soy blend control noodles than in wheat-extruded soy blend control noodles, but lower residue values were found in wheat-extruded soy blend noodles containing SSL and SMDS. However, wheat-extruded soy blend doughs did not give the homogeneous masses after mixing; therefore, hull particles fell off during storage.

Soy protein isolate is prepared by removing the water-insoluble polysaccharides, as well as the oligosaccharides and other low-molecular weight components; but still the residue values of wheat-soy protein isolate blend noodles were higher than those of wheat flour noodles. This result could be due to the more amylose and soluble protein in the cooking water with soy protein isolate substitution.

As salt was added to the noodles, the residue values were high in comparison with those of wheat flour and of wheat-defatted soy blend noodles with or without surfactants. This could be caused by the greater release of amylose into the cooking water with the addition of salt.

The above data show that the residue values are significantly affected by the presence of surfactants, soy products, and salt. Generally, the residue values were increased by incorporation of soy products and salt and decreased by addition of surfactants. There was a significant high correlation between residue values and amylose obtained in the cooking water; the less amylose found, the less residue values estimated. Degree of disintigration is one of the principal cooking quality measurements in pasta products. Concerning the residue values, the presence of surfactants improved the cooking quality, whereas soy products substitution had an adverse effect. Fortification of noodles with soy products increased the extracted solids in the cooking water but this is not considered as a significant loss from the standpoint of nutrition because the carbohydrates in soy products are not digestible.

Effect of Surfactants, Soy Products, or Salt on the Extractability of Water-Soluble Protein at Various Cooking Times

Figs. 7 to 10 show the results of extracting soluble protein at various cooking times from the following: wheat flour noodles, wheat flour noodles containing surfactants, wheat-soy blend noodles, wheat-soy blend noodles containing surfactants, and wheat flour and wheat-defatted soy blend noodles with or without surfactants and salt. The amount of protein is expressed as per cent of nitrogenous materials extracted.

For wheat flour control noodles, extractable protein at 7, 14, and 21 min. cooking time was 6.60%, 6.82%, and 6.49%, respectively. Only SSL showed a marked decrease of soluble protein in wheat flour noodles. With the addition of surfactants, the per cent of extractable protein ranged from 4.73 to 8.03% (Fig. 7). When EMG, MG, and ST were present in the wheat flour noodles, the solubility of protein showed a remarkable increase as noodles were cooked for 14 min., but with polysorbate 60, SMP, and SMDS the soluble protein tended to decrease with increasing cooking time. For GMS and SDS, solubility of protein showed minor changes with increasing cooking time. Noodles fortified with soy products increased the solubility of protein remarkably. Soy protein isolate substitution showed most increase in solubility of protein, followed by defatted soy flour, extruded soy meal, and full-fat soy flour. With the addition of surfactants, the per cent of extractable protein ranged between 10.17 and 12.64% for wheat-soy

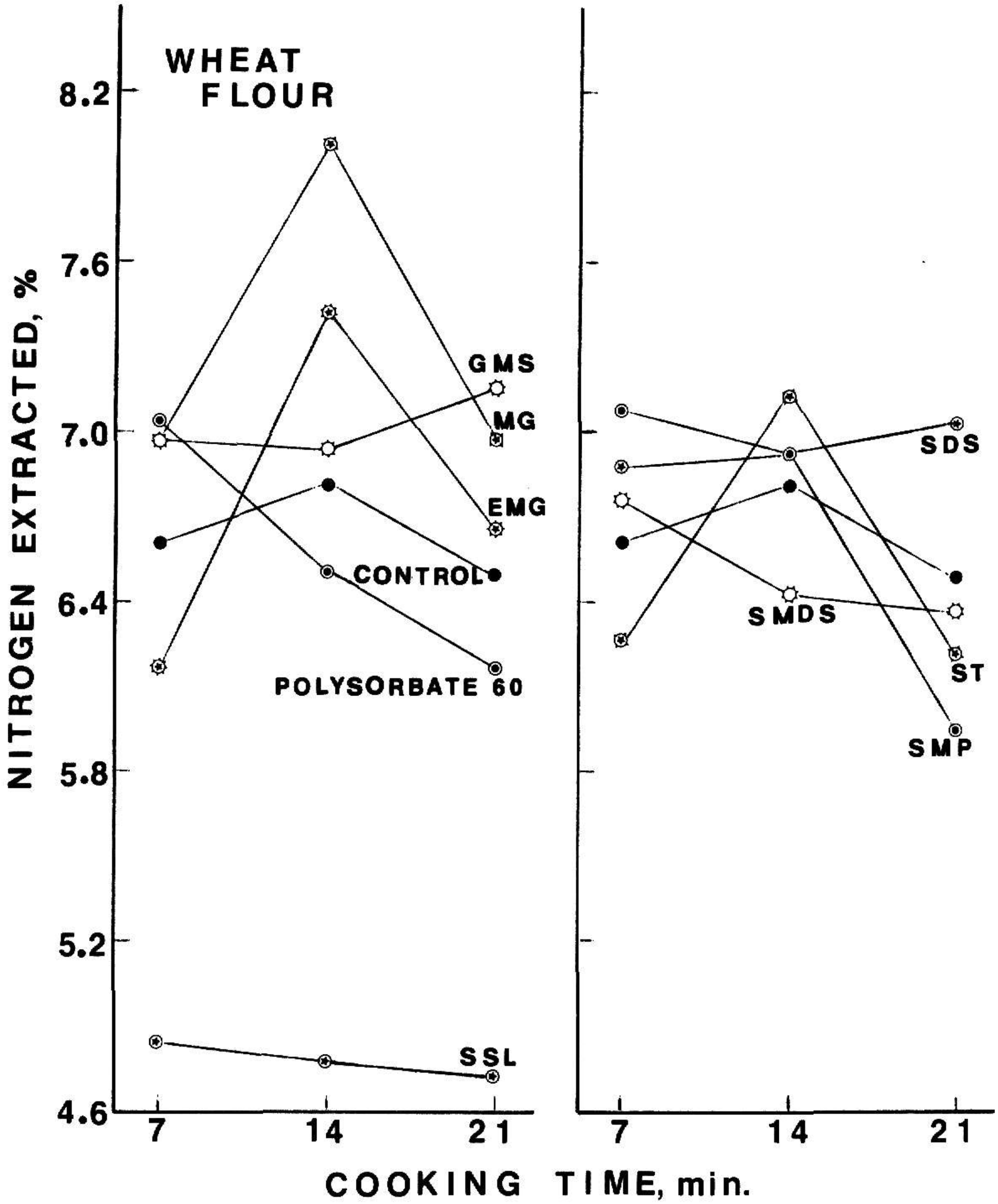


Fig. 7. Effect of surfactants on extractability of water-soluble protein of wheat flour noodles at different cooking times.

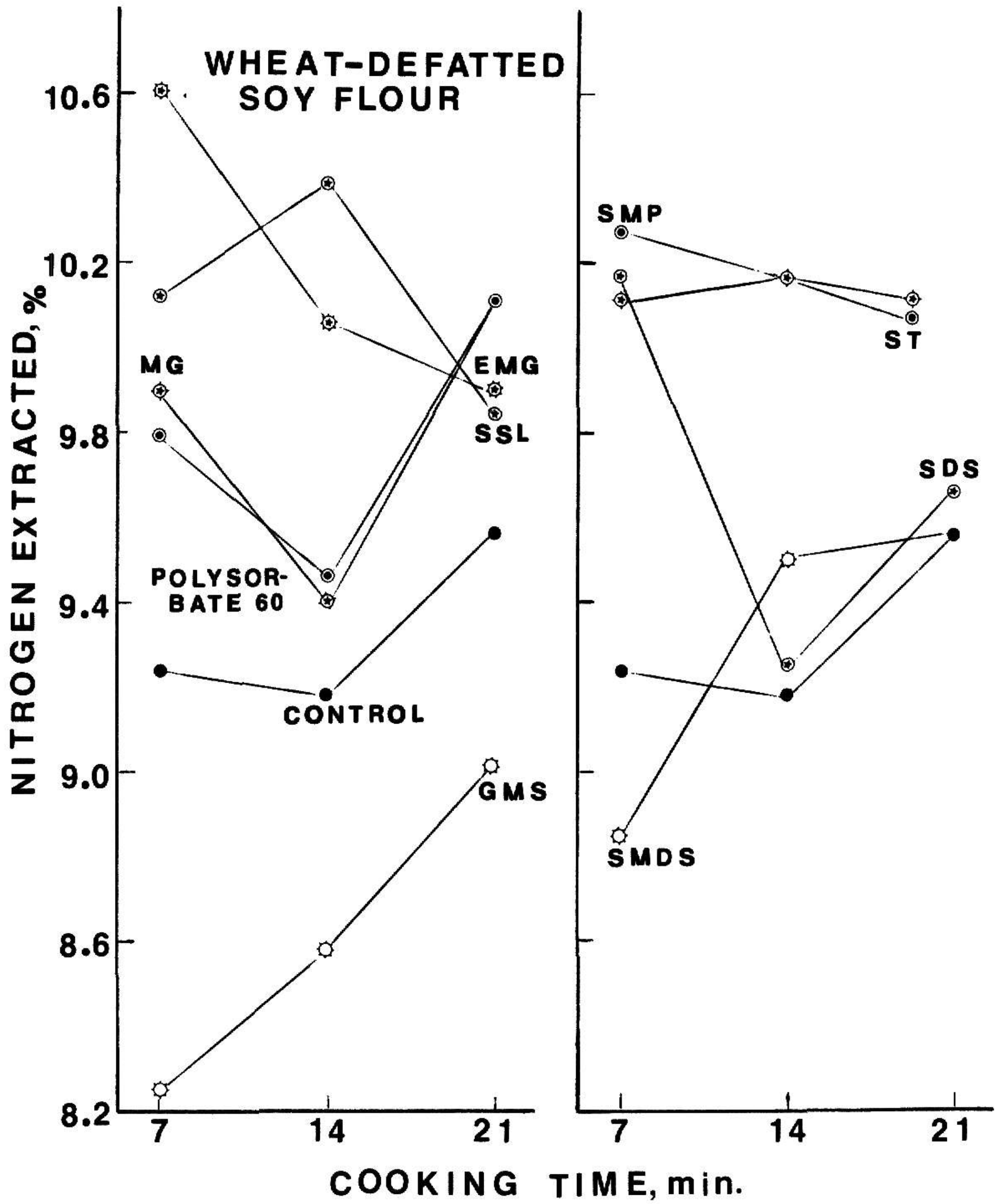
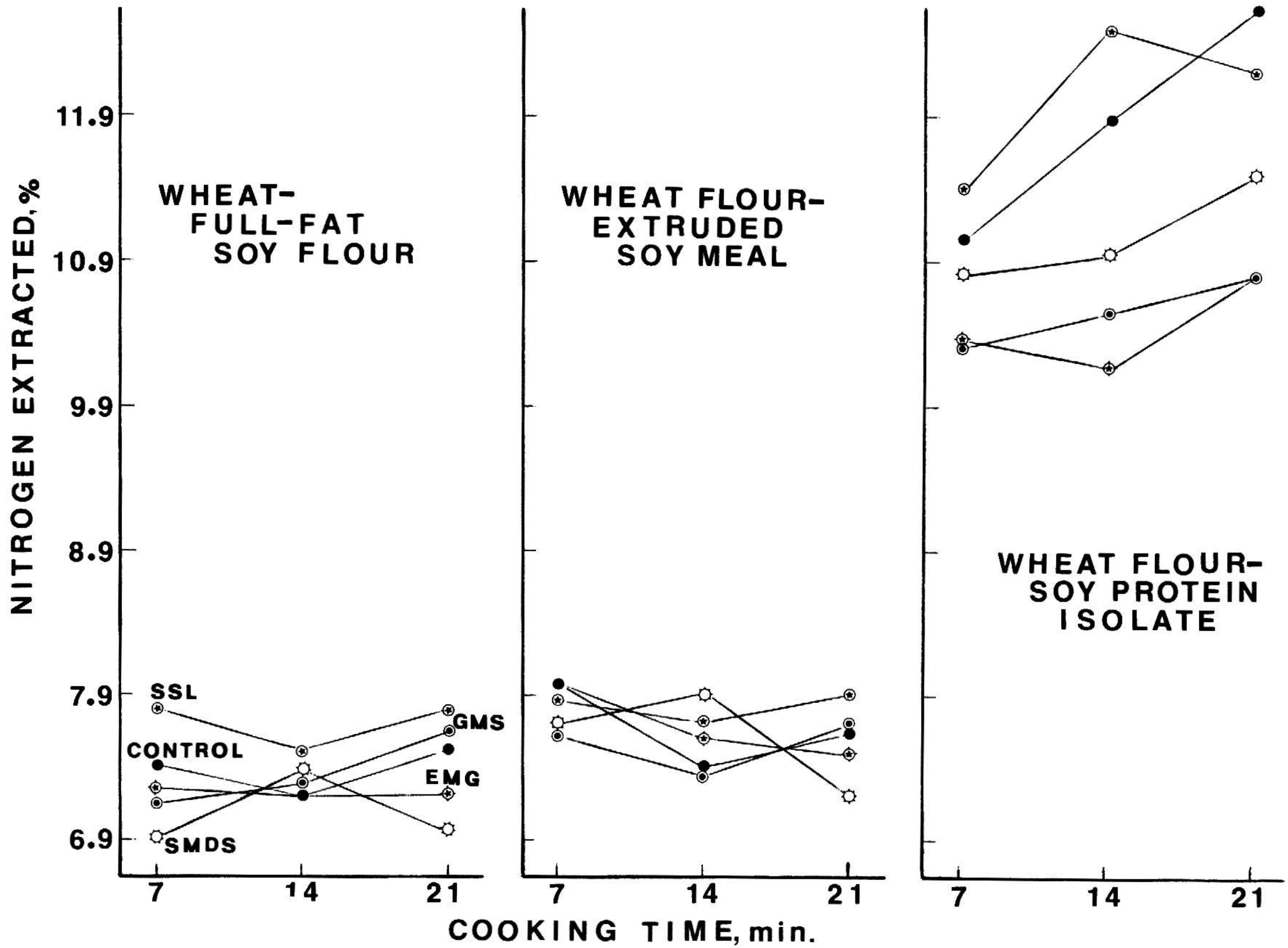


Fig. 8. Effect of surfactants on extractability of water-soluble protein of wheat-defatted soy blend noodles at different cooking times.

Fig. 9. Effect of surfactants on extractability of water-soluble protein of wheat-soy blend noodles at different cooking times.


NITROGEN EXTRACTED, %
11.9
10.9
9.9
8.9
7.9
6.9
WHEAT-
FULL-FAT
SOY FLOUR
SSL
CONTROL
SMDS
GMS
EMG
WHEAT FLOUR-
EXTRUDED
SOY MEAL
WHEAT FLOUR-
SOY PROTEIN
ISOLATE
7
14
21
COOKING TIME, min.

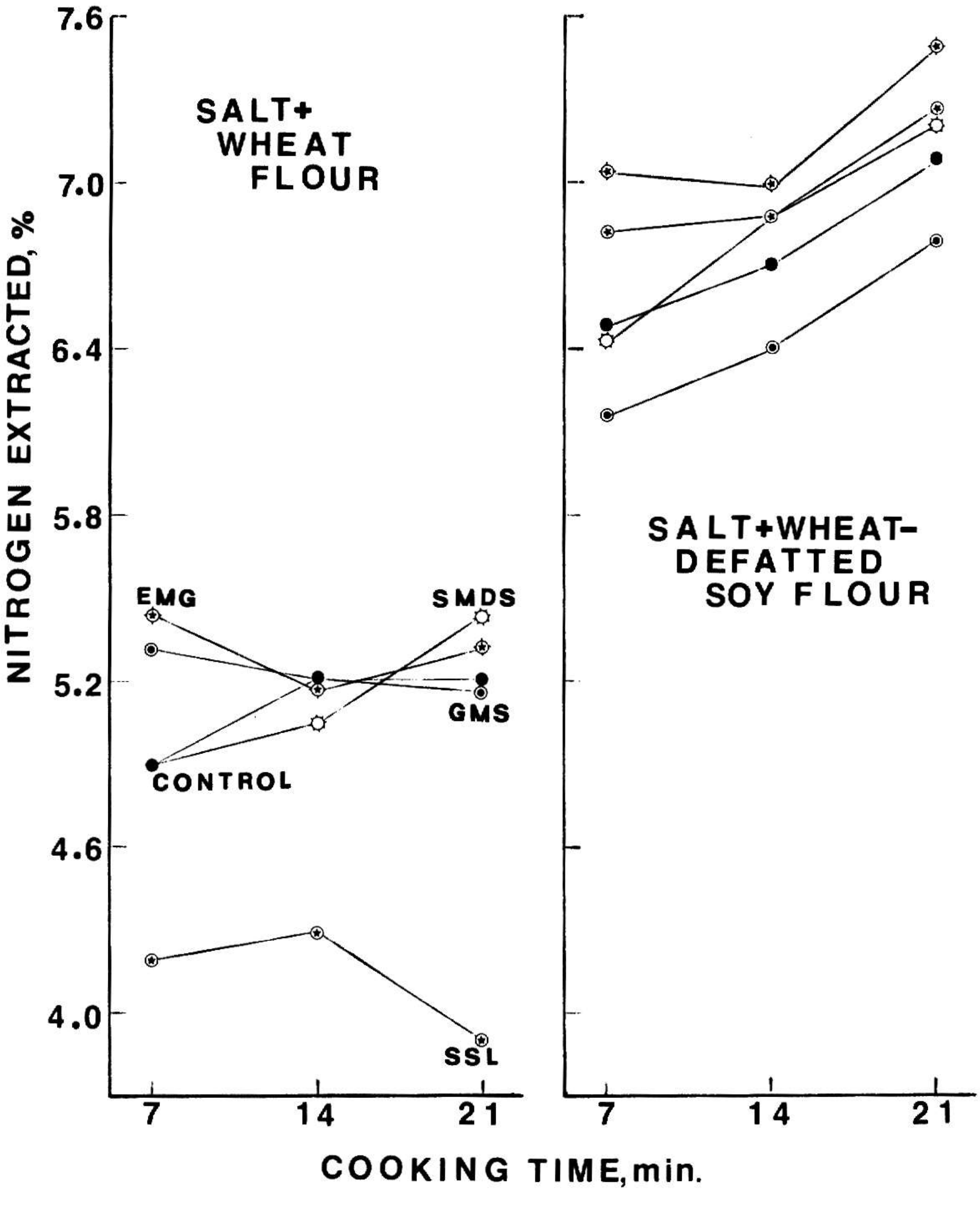


Fig. 10. Effect of salt on extractability of water-soluble protein of wheat flour and wheat-defatted soy blend noodles with or without surfactants at different cooking times.

protein isolate blend noodles, 8.25 and 10.61% for wheat-defatted soy blend noodles, 7.20 and 7.97% for wheat-extruded soy blend noodles, 6.93 and 7.81% for wheat-full-fat soy blend noodles (Figs. 8-9).

For wheat-defatted soy control noodles the change in soluble protein was slightly decreased with 14 min. cooking time, but showed some increase with 21 min. Addition of MG, polysorbate 60, and SDS to the wheat-defatted soy doughs showed a similar pattern as the control noodles, although the degree of change was higher than control noodles. GMS only showed the most pronounced decrease in solubility of protein than any other surfactants used in the wheat-defatted soy blend noodles. With EMG and SMP, the soluble protein was decreased as the cooking time increased, but with SMDS the increase of soluble protein was obtained with increasing cooking time. SSL showed the highest soluble protein per cent with 14 min. cooking time. The presence of ST showed a slight change in solubility of protein with cooking time.

For wheat-full-fat soy control noodles, the per cent of soluble protein was the lowest at 14 min. cooking time. Addition of SSL to wheat-full-fat soy dough showed the same pattern as control noodles but adding SMDS had the opposite effect. The presence of GMS increased the soluble protein as the cooking time increased, but EMG showed minute decrease in solubility with cooking time.

The wheat-extruded soy control noodles had the highest solubility per cent at 7 min. cooking time. With SSL and GMS, the per cent of soluble protein was highest at 21 min. cooking time, but with SMDS was obtained at 14 min. The presence of EMG decreased the solubility as cooking time increased.

The wheat-soy protein isolate control noodles and adding SMDS and GMS to the control doughs showed increasing protein solubility with increasing cooking time. With SSL the highest per cent of protein solubility was obtained at 14 min. cooking time, while with EMG the lowest per cent of protein solubility was at 14 min. cooking time.

Salt was added to the wheat flour dough, solubility of protein was increased rapidly at 14 min. cooking time and remained constant after 14 min. Addition of SMDS to the control dough increased the protein solubility with increasing cooking time. When GMS was added, the protein solubility decreased as cooking time increased. Only SSL showed a considerable decrease in solubility of protein.

When wheat-defatted soy control noodles contained salt, the protein solubility was increased with increasing cooking time. Also the presence of SMDS, GMS, and SSL increased the protein solubility with increasing cooking time but not for EMG. GMS was the most effective in decreasing extractable protein.

By isolation and characterization studies of water-soluble wheat flour protein, Fish and Abbott (61) reported that albumin was the main component of water-soluble wheat flour protein. Unlike the water-soluble wheat flour protein, the major soybean proteins are globulins, which are insoluble at their isoelectric point. These proteins are soluble in water or dilute salt solutions at pH values above or below their isoelectric point.

Four important variables influencing the solubility of globular protein have been recognized (63): a) pH, b) ionic strength, c) the dielectric properties of the solvent, d) temperature.

Addition of each of surfactants to the wheat flour doughs and to the wheat-soy blend doughs may change the pH and ionic strength of the noodle doughs. Of the surfactants used, SSL was the only ionic surfactant. When wheat flour dough contained SSL, protein solubility was decreased considerably, suggesting an interaction between SSL and water-soluble wheat protein.

The physical state, such as pH and ionic strength, changed markedly; particularly if more than one species of emulsifier molecules were present. As GMS and phospholipids co-existed in the wheat-defatted soy dough, decrease in protein solubility was observed. It is suggested that interaction between GMS and water-soluble protein could occur.

When compared to the wheat-defatted soy blend noodles, a decrease in protein solubility was observed with wheat-full-fat soy blend and wheat-extruded soy blend noodles, whereas the increase of protein solubility was obtained from the wheat-soy protein isolate noodles. Fullington (64) has shown that wheat flour proteins which are soluble in water form insoluble lipid-protein complexes with phospholipids such as triphosphoinositide or phosphatidyl serine. Since soybean contains 2-5% of phosphatides (65), the decrease in solubility with wheat-full-fat soy blend noodles and wheat-extruded soy blend noodles could indicate the formation of these insoluble complexes between water-soluble wheat protein or water-soluble soy protein and phospholipids of soy products.

During the processing of soy protein isolate, most of fat and polysaccharides are removed. For wheat-soy protein isolate blend noodles, the increase in protein extractability could be from the physical properties of soy protein isolate.

The presence of salt in the wheat flour noodles and wheat-defatted soy blend noodles decreased the protein solubility, when compared to those noodles without salt. This decrease in solubility in the presence of salt is likely due to the interaction of sodium and chloride ions with the negative and positive charges on the protein molecules and hence solubilities are modified. Likewise, cohesiveness of the protein may be modified by addition of ionic materials.

From these results it can be seen that surfactants, or soy products, or salt, or the presence of more than one of these influenced the extractability of water-soluble protein at different cooking times. The degree of extractability depends on the surfactants and soy products, and the presence of salt. However, the observed differences of protein extractability as affected by surfactants in the wheat flour noodles and in the wheat-soy blend noodles at various cooking times cannot be explained by this work.

To minimize protein losses during cooking, surfactants were added in noodle making. However, this protein loss was not reduced by adding surfactants except for SSL and GMS, which reduced the solubility of protein in the wheat flour noodles and in the wheat-defatted soy blend noodles with or without salt. Fortified noodles made from soy products increased the soluble protein in the cooking water. Of the fortified noodles, those made from full-fat soy flour showed a lesser degree of soluble protein losses than any of the others.

Organoleptic Evaluation of Wheat Flour and Wheat-Soy Blend Noodles

The results from taste-panel study were analyzed statistically. Analysis of variances of the noodle characteristics and acceptability as affected by flours, surfactants, and salt is shown in Tables 10-15. The

TABLE 10

Means Due to the Effect of Flours and Surfactants on Noodle Characteristics and on Acceptability.

Treatment	Appearance	Flavor	Texture	Acceptability
flour				
wheat	3.30*	3.30*	3.84*	3.42**
wheat-defatted soy	3.20*	3.22*	3.42*	3.56*
wheat-full-fat soy	3.40*	3.18*	3.40*	3.22 *
wheat-soy protein isolate	3.66	3.24*	3.58*	3.66*
wheat-extruded soy meal	2.30	2.36	2.32	2.16
surfactant				
control	3.46*	3.06*	3.22*	3.10 *
SSL	2.38	2.94*	3.08*	2.54
EMG	3.24*	3.12*	3.14*	3.36*
GMS	3.32*	3.02*	3.18*	3.34**
SMDS	3.46*	3.16*	3.58	3.68
L.S.D.	0.236	0.239	0.235	0.244

[a]5% level of significance

Non-significant groupings connected by column of asterisks.

TABLE 11

Analysis of Variance: Wheat Flour and Wheat-Soy Blend Noodles With or Without Surfactants

Source of Variation	Appearance			Flavor			Texture			Acceptability		
	df	MS	F	df	MS	F	df	MS	F	df	MS	F
Flour	4	6.67	37.58**	4	3.87	21.36**	4	6.73	38.17**	4	9.20	48.37**
Surfactant	4	5.12	28.85**	4	0.19	1.02	4	0.97	5.50**	4	4.51	23.71**
Member	4	0.41	2.33	4	0.49	2.73**	4	0.11	0.65	4	1.54	8.08**
Flour x Surfactant	16	0.76	4.28**	16	0.38	2.12**	16	0.54	3.04**	16	1.05	5.53**
Error	96	0.18		96	0.18		96	0.18		96	0.19	

**5% level of significance

TABLE 12

Means Due to the Effect of Flours, Surfactants, and Salt on Noodle Characteristics and on Acceptability.[a]

Treatment	Appearance	Flavor	Texture	Acceptability
flour				
wheat	3.39*	3.20*	3.48*	3.43*
wheat-defatted soy	3.36*	3.12*	3.50*	3.46*
surfactant				
control	3.75*	3.25*	3.58*	3.75**
SSL	2.25	3.10*	3.17 *	2.47
EMG	3.40 *	3.15*	3.50**	3.50 *
GMS	3.65**	3.12*	3.33 **	3.57 *
SMDS	3.82*	3.17*	3.87	3.92*
L.S.D.	0.267	0.213	0.224	0.305
salt				
no salt	3.25	3.26	3.45*	3.47*
with salt	3.50	3.06	3.53*	3.42*
L.S.D.	0.169	0.135	--	--

[a]5% level of significance

Non-significant groupings connected by column of asterisks.

TABLE 13

Analysis of Variance: Wheat Flour and Wheat-Defatted Soy Blend Noodles With or Without Salt and Surfactants.

Source of Variation	Appearance			Flavor			Texture			Acceptability		
	df	MS	F	df	MS	F	df	MS	F	df	MS	F
Flour	1	0.02	0.13	1	0.16	1.41	1	0.01	0.08	1	0.02	0.10
Salt	1	1.56	8.76**	1	1.00	8.80**	1	0.16	1.28	1	0.06	0.27
Surfactant	4	8.42	47.25**	4	0.07	0.58	4	1.41	11.27**	4	6.42	27.71**
Member	4	0.46	2.59**	4	0.29	2.56**	4	0.25	1.98	4	0.95	4.08**
Flour x Salt	1	0.12	0.69	1	0.00	0.00	1	0.16	1.28	1	0.12	0.53
Flour x Surfactant	4	0.26	1.46	4	0.25	2.23	4	0.34	2.68**	4	0.79	3.41**
Salt x Surfactant	4	0.35	1.96	4	0.06	0.50	4	0.12	0.98	4	0.27	1.56
Flour x Salt x Surfactant	4	0.49	2.72**	4	0.37	3.25**	4	0.92	7.37**	76	0.60	2.60**
Error	76	0.18		76	0.11		76	0.13			0.23	

**5% level of significance

TABLE 14

Means Due to the Effect of Flours and Surfactants on Noodle Characteristics and on Acceptability.[a]

Treatment	Appearance	Flavor	Texture	Acceptability
flour				
wheat	3.30*	3.23*	3.35*	3.36*
wheat-defatted soy	3.28*	3.18*	3.48*	3.50*
surfactant				
control	3.50***	3.35**	3.65**	3.70**
SSL	2.25	3.20 **	3.25 **	2.55
EMG	3.25 ***	3.40 ***	3.40 ***	3.55 **
GMS	3.40 ***	3.15 **	3.20 **	3.45 **
MG	3.00 **	3.05 **	3.65**	3.40**
polysorbate 60	3.25 ***	3.05 **	3.10 **	3.25 **
SMP	3.80**	2.30 **	3.45 **	3.70**
SMDS	3.70**	3.55*	3.90*	4.05*
SDS	3.85*	3.30**	3.70**	3.70**
ST	2.90 *	2.95 *	2.85 *	2.95 *
L.S.D.	0.401	0.305	0.308	0.396

[a]5% level of significance

Non-significant groupings connected by column of asterisks.

TABLE 15

Analysis of Variance: Wheat Flour and Wheat-Defatted Soy Blend Noodles With or Without Surfactants.

Source of variation	Appearance			Flavor			Texture			Acceptability		
	df	MS	F	df	MS	F	df	MS	F	df	MS	F
Flour	1	0.01	0.05	1	0.06	0.54	1	0.42	3.57**	1	0.49	2.51
Surfactant	9	2.35	11.71**	9	0.30	2.55**	9	1.02	8.65**	9	1.84	9.41**
Member	4	0.63	3.13**	4	0.44	3.78**	4	0.40	3.42**	4	0.88	4.52**
Flour x Surfactant	9	0.40	1.98	9	0.19	1.64	9	0.64	5.45**	9	0.90	4.58**
Error	76	0.20		76	0.12		76	0.12		76	0.20	

**5% level of significance

non-significant groups were connected by column of asterisks. Acceptability of noodles was judged by the taste panel according to their preference.

Appearance As shown in Table 11, the noodles were significantly different in appearance among the five flours and four surfactants used. There were no significant differences by using soft wheat flour, wheat-defatted soy blend, wheat-full-fat soy blend for making noodles, but there were significant differences by using wheat-soy protein isolate blend and wheat-extruded soy meal blend. Appearance was badly affected by replacing wheat flour with 18% extruded soy meal. Wheat-soy protein isolate blend noodles showed best appearance. There were no significant differences in appearance between control noodles and noodles containing EMG, GMS, and SMDS. However, SSL showed a deleterious effect in appearance (Table 15). There were three groups that were not significantly different and two groups that were significantly different in comparison with control noodles (Table 14). Addition of SSL and ST to the noodle doughs affected the appearance markedly. Checking or cracking occurred with adding SSL and ST. The presence of salt affected the appearance significantly (Table 12). The panel preferred the noodles made with addition of salt.

Flavor. Noodles fortified with soy products and wheat flour control noodles showed no significant differences in flavor except for the wheat-extruded soy meal blend noodles (Table 10). SSL, EMG, GMS, and SMDS were added to the five different flours, no change in flavor was observed. From the data shown in Table 14, the flavor scores of control noodles had two groups which were not significantly different and one group which was significantly different. Addition of SMDS showed the highest mean in flavor score, but with ST had the lowest mean. Addition of salt changed the flavor significantly. The flavor of noodles prepared with salt was preferred.

Texture. Including soy products in noodle making produced no significant differences in texture except for the extruded soy meal (Table 10). The texture of wheat flour noodles had the highest mean, followed by wheat-soy protein isolate blend noodles, wheat-defatted soy blend noodles, and wheat-full-fat soy blend noodles, in that order. There were no significant differences in texture by adding SSL, EMG, and GMS to the wheat flour and wheat-soy blend doughs. However, a significant difference in texture was observed with the addition of SMDS to these doughs. There were significant differences in texture due to the surfactants used (Table 15). There were two groups that were not significantly different and three groups that were significantly different in comparison with the texture of control noodles (Table 10). Addition of ST to these doughs only showed a significant difference from the control noodles in texture. There were no significant differences in texture due to the salt.

Acceptability. Acceptability of wheat flour noodles was not significantly different from wheat-defatted soy blend noodles and wheat-soy protein isolate blend noodles. Also there were no significant differences between wheat flour noodles and wheat-full-fat soy blend noodles. With the single exception of wheat-extruded soy blend noodles which were moderately unacceptable, soft wheat flour noodles and other wheat-soy blend noodles were acceptable. Addition of SMDS to the wheat flour and various wheat-soy blend doughs produced noodles which improved the acceptability, whereas adding SSL showed the opposite trend. The presence of various surfactants in noodle doughs affected the acceptability of wheat and wheat-defatted soy blend noodles. Compared to the acceptability of the control noodles, there were two groups that were not significantly different and that were significantly different (Table 14). Addition of SMDS to the doughs had the highest acceptability score, but adding SSL and ST made moderately unacceptable noodles. The presence of salt in the noodle doughs made no change in acceptability.

In summing up the taste-panel study, the noodles made from wheat flour alone and wheat-soy blend were significantly different in appearance, flavor, texture, and acceptability (Table 11), but there were no significant differences in the characteristics studied due to the wheat flour and wheat-defatted soy blend with or without salt. Significant differences were observed in appearance, flavor, texture, and acceptability due to the surfactants added (Table 15). Addition of salt changed the texture and acceptability of noodles but not appearance and flavor (Table 13).

From the statistical analysis of the organoleptic test, it may be concluded that soft wheat flour alone and wheat-soy blend can be used for making acceptable noodles except for wheat-extruded soy meal blend, since wheat-extruded soy meal blend noodles appeared to be moderately unacceptable. A slight change in flavor was observed by adding surfactants. Addition of SSL and ST to the noodle doughs had a deleterious effect on noodle characteristics studied, whereas improvement on the characteristics was observed with SMDS and SDS.

SUMMARY AND CONCLUSIONS

Attempts have been made to determine the amounts of soluble starches and proteins and residues in cooking water of noodles that contained surfactants and soy products to improve not only the cooking quality but also their nutritional value. The improvement on cooking quality was significantly correlated with the degree that stickiness or pastiness developed during cooking. With the exception of SSL and soy protein isolate, results indicated that the presence of surfactants and soy products in noodle doughs yielded products with improved cooking quality, thus producing firmer, less sticky, and more elastic noodles after cooking.

The amounts of released amylose and residue in noodle cooking water decreased in relation to the type of surfactants used. A greater decrease of amylose in noodle cooking water was observed with the wheat-soy blend noodles with added surfactants and a change in the decreasing order of amylose was observed in the presence of surfactants and soy products. This indicated that surfactants had varied amylose binding capacities and exerted synergistic effect with the simultaneous presence of phospholipids in soy products.

The amounts of extractable water-soluble protein in noodle cooking water further suggests that SSL or CMS and phospholipids in soy products could form insoluble complexes with water-soluble wheat or soy proteins.

Results showed that cooking quality of noodles improved with the inclusion of SMDS or SDS and defatted or full-fat soy flour.

Some manufacturers of canned and precooked frozen pasta products add egg albumin (from 0.75 to 2%) or gum gluten to durum semolina to prevent softening due to excessive cooking and reheating. The use of SMDS or SDS for eliminating pastiness and softening could offer an economical advantage for consumer use, canned and precooked frozen noodles.

It was concluded, when soft wheat flour alone or a blend of semolina and other flours are used, a level of 1.0 to 1.5% SMDS or SDS based on flour weight is recommended for noodle manufacturing.

Durum wheat starches had considerably higher iodine absorption values than other starches (66). Since starch chemists believe that the linear fraction of starch with iodine and with higher fatty acids and surfactants had similar helical configurations, it may be concluded that less amounts (0.5 to 1.0%) of SMDS or SDS could be used to produce nonpasty noodles from No. 1 semolina.

In conclusion, the uses of defatted soy flour or full-fat soy flour for fortified noodle production and use of SMDS or SDS or the two together in noodle manufacturing are recommended to suit consumer tastes, and for canned and precooked frozen noodles. Noodles reinforced with these products will be firm during overcooking and reheating so they will be acceptable and palatable.

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EFFECTS OF SURFACTANTS, SOY PRODUCTS, AND SALT ON AMYLOGRAPH PROPERTIES OF FLOUR SUSPENSIONS AND COOKING QUALITY OF NOODLES

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Reported here are results of investigating the cooking quality of noodles by adding surfactants and salt, fortifying noodles with various soy products, and evaluating soft wheat flour for possible use in noodle making.

Visco-amylograph studies showed that different surfactants, soy products, and salt varied in effects on wheat flour and wheat-soy blend pasting properties, by restricting swelling and solubilization of starch granules. SSL, SMDS, and SMP exerted the most pronounced effect while GMS and MG had the least effect. Even though surfactants restricted the swelling and solubilization of starch granules as measured with the visco-amylograph, there was no correlation with the amount of soluble starch leached during cooking of noodles as measured by the determining amylose in the cooking water.

With the single exception of SSL, all of the surfactants used in cooking quality evaluation tests showed appreciable decrease in amylose and residue in the cooking water; of the surfactants studied, SMDS, SDS, and MG exerted a considerable effect. However, SSL and GMS were the only surfactants that decreased the extractable soluble protein in the cooking water.

Noodles fortified with soy products, except wheat-soy protein isolate blend noodles, decreased the amount of released amylose in the cooking water; whereas amounts of residue and soluble proteins were increased. Of the soy products investigated, including full-fat soy flour decreased residues and soluble proteins the most.

Adding salt increased amylose and residue in the cooking water, but tended to decrease the amount of soluble protein.

A significant correlation was shown between leached amylose and residue in the cooking water; the more amylose released, the more residue obtained. However, we cannot explain the observed differences of soluble protein as affected by surfactants. Further study is needed.

From organoleptic evaluation, soft wheat flour noodles and wheat-soy blend noodles appeared to be acceptable except for the wheat-extruded soy blend noodles.

Pastiness is due mainly to soluble starch released in the cooking. The results of the present investigation suggest that the use of SMDS or SDS may eliminate the characteristic pastiness, sticking and gluey consistency when cooking noodles. Furthermore, noodles fortified with defatted soy flour or full-fat soy flour improved not only cooking quality of noodles but also nutritional value, resulting in very palatable, firm, less sticky, and acceptable noodles.

It is also suggested that soft wheat flour alone or a blend of semolina and of other flour classes can be used for the manufacture of acceptable noodles by adding 1.0 to 1.5% SMDS or SDS based on flour weight.

Durum wheat starches had considerably higher iodine absorption values than other wheat starches, which suggests that less SMDS or SDS would be used; 0.5 to 1.0% based on flour weight for nonpasty noodles, if No. 1 semolina raw material was used.

In summary, the uses of defatted soy flour or full-fat soy flour for making fortified noodles and use of SMDS or SDS or the two together in noodle manufacturing are recommended to suit consumer tastes, and for canned and precooked frozen noodles. Noodles reinforced with these products will be firm during overcooking and reheating so they will be acceptable and palatable.