Functional Properties of Some High Protein Products in Pasta

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The rheological properties of doughs, containing durum semolina, soft red winter (SRW), and hard red spring (HRS) wheat farina, supplemented with six high-protein derivatives from soybean and cottonseed meal, were examined. The C.W. Brabender Do-Corder was used to evaluate the rheological properties of each dough with different levels of the high-protein products. The water absorption was significantly increased while a decrease in the mechanical tolerance index (MTI) was noticed. Dough stability differed significantly from sample to sample. Cottonseed meal did not increase water absorption as greatly as other protein isolates or concentrates and did not have a significant effect on the MTI. The spaghetti quality of each high-protein composite was also evaluated. These studies suggest that the high-protein products increased dough strength but lowered spaghetti quality when used for making pasta.

Durum wheat is the raw material used to produce good quality semolina for good quality pasta production. To form the plastic type of dough used for pasta processing, semolina is mixed with water representing 30–32% of the weight of the semolina. Because a slow-speed ribbon-type mixer is employed under vacuum, no gluten development is involved in the gentle mixing process. The dough is then kneaded under controlled conditions of vacuum and temperature and finally extruded (Hummel, 1966). Because this process requires closely controlled conditions, the viscous and elastic properties of the semolina dough are important.

Mixing of pasta dough is different than mixing of bread dough. Mixing in breadmaking is considered a critical step to blend the ingredients and especially to develop the gluten. Bread doughs contain primarily wheat flour and approximately 65% water; they are mixed in high-speed, pin-type mixers usually in the presence of air. Thorough blending of ingredients is quickly attained, whereas gluten development requires additional mixing. The viscous and elastic properties of a dough are primarily due to the properties of its gluten while the viscoelasticity of gluten and dough is primarily due to the network of protein molecules (Pyler, 1973). The rheological properties of the network are affected by the number and types of cross-links within the protein molecules (Bloksma, 1971). This type of gluten network development by mixing is not required in pasta dough formation.

Durum semolina dough at ordinary stress is more rigid and viscous than bread dough as reported by Glucklich and Shelef (1962). The elastic deformation is less linear for bread than for pasta dough while the viscous deformation is less linear for pasta dough than for bread dough.

Different ingredients affect the mixing pattern of pasta dough due to the physical and chemical composition of each ingredient in the blend. This study was undertaken primarily to investigate the functional properties of some high-protein ingredients in the pasta when processed with durum semolina, soft red winter (SRW), and hard red spring (HRS) wheat farina.

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MATERIALS AND METHODS

Samples. The six high-protein products used in this study are listed in Table I.

Samples of HRS and SRW wheat coarse granular farina were obtained by milling the wheat samples on a Buhler experimental mill using the procedure and the milling flow reported by Seyam et al. (1973). The sample of semolina was Durakota No. 1 supplied by the North Dakota State Mill and Elevator.

Blends were prepared by adding 5.0, 10.0, and 20.0% of high-protein products to semolina. Farinas from HRS and SRW wheats were tested with a 10.0% addition of each high-protein material. Handling problems developed when higher levels of added protein materials were used. The doughs were very sticky, so it was not practical to use a 15.0–20.0% level for producing pasta.

Dough Rheology Testing. Dough rheology of samples was determined with a C.W. Brabender Do-Corder (C.W. Brabender Instruments, Inc.) Model Do-V153 under the following conditions: Indicator (scalehead) adjustment, X1; connector setting, 1:1; rpm of dynamometer, 60; shift position, 0; Sigma blade 50-g mixer.

Curves were centered on the 500 B.U. line. A total running time of 20 min was used. Terms used throughout this work to describe farinograms are arrival time, stability time, peak time, departure time, mechanical tolerance index (MTI), and time to break down as described by Shuey et al. (1972).

Experimental Spaghetti Processing. Spaghetti samples were processed on a laboratory unit as described by Harris and Sibbitt (1942), using the modifications reported by Walsh et al. (1970).

Spaghetti color, cooked weight, cooking loss, and spaghetti firmness were evaluated as described by Dick et al. (1974).

RESULTS AND DISCUSSION

Dough Rheology. The rheological properties of semolina dough with different levels of soy or cottonseed meal products are shown in Table II. Table III shows the effect of 10% added protein on HRS and SRW wheat farina.

The addition of soy or cottonseed meal products to HRS or SRW wheat farina increased Do-Corder water absorption markedly. SPI-2 when added to all the samples, showed the highest water absorption. In this study the soy protein isolates tended to increase the water absorption more than cottonseed meal or soy protein concentrates. High-protein materials at the 10% level showed a no-

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Table I. Semolina, Soy, and Cottonseed Meal Products Used for Pasta Processing

source	commercial name	total protein,[a] %	producing company
soybean	promine F	78.6	Central Soya
soybean	promine D	76.2	Central Soya
soybean	promine R	72.2	Central Soya
soybean	promosoy 100	57.1	Central Soya
soybean	nutrisoy flour T	46.4	Archer Daniel Midland
cottonseed	cottonseed meal	57.5	National Cottonseed Producers Association

[a] Dry matter basis. The factor used to convert nitrogen to protein was 6.25 for soy and cottonseed products.

Table II. Rheological Properties of Semolina Dough Supplemented with Different Levels of Soy and Cottonseed Meal Derivatives[a]

sample	water absorption, %	arrival time, min	stability, min	peak time, min	departure time, min	MTI, B.U.
semolina (control)	51.6	1.7	2.0	2.8	3.7	105
5% addition						
SPI-2	57.8	1.9	2.2	2.4	4.1	95
SPI-1	56.8	2.5	2.6	3.5	5.1	55
SPI-3	57.2	2.4	2.7	3.6	5.1	70
SPC	56.2	2.1	2.2	2.8	4.3	85
NSF	54.2	2.3	2.2	3.0	4.5	80
CSM	53.2	1.9	2.4	2.8	4.3	95
10% addition						
SPI-2	68.2	2.0	2.3	2.6	4.3	80
SPI-1	62.8	1.8	4.3	3.1	6.1	60
SPI-3	60.4	2.2	3.8	3.3	6.0	55
SPC	61.3	2.1	2.4	2.9	4.5	65
NSF	58.8	2.3	2.3	3.1	4.6	75
CSM	55.2	2.2	2.2	3.0	4.4	95
20% addition						
SPI-2	88.0	2.5	2.2	2.9	4.7	70
SPI-1	77.6	2.7	3.9	3.6	6.6	40
SPI-3	69.4	2.1	6.8	3.7	8.9	20
SPC	70.3	2.2	2.7	3.0	5.9	45
NSF	65.6	2.4	3.2	3.5	5.6	60
CSM	58.2	2.1	2.4	2.6	4.5	100

[a] SPI-1 = promine D, SPI-2 = promine F, SPI-3 = promine R, SPC = promosoy 100, NSF = nutrisoy flour T, CSM = cottonseed meal.

Table III. Rheological Properties of SRW and HRS Wheat Dough with 10% Soy and Cottonseed Products

sample	water absorption, %	arrival time, min	stability, min	peak time, min	departure time, min	MTI, B.U.
soft red winter wheat farina						
farina (control)	54.4	2.0	3.0	3.5	5.0	80
SPI-2	71.0	2.0	2.0	3.0	4.0	80
SPI-1	65.7	3.0	7.0	5.5	11.0	65
SPI-3	60.0	3.0	4.5	4.5	7.5	60
SPC	63.1	2.0	8.0	4.5	10.0	40
NSF	61.1	3.0	4.5	4.5	7.5	60
CSM	56.9	2.5	3.0	3.5	5.5	65
hard red spring wheat farina						
farina (control)	60.2	3.0	8.5	5.0	11.0	65
SPI-2	75.6	2.5	2.5	2.0	5.0	85
SPI-1	69.2	4.0	10.0	7.5	14.0	60
SPI-3	65.9	5.5	7.5	8.0	13.0	30
SPC	68.2	3.5	9.5	5.5	13.0	40
NSF	64.8	3.5	8.0	6.5	11.5	60
CSM	62.0	3.0	9.5	4.5	12.5	50

ticeable increase of the arrival time for HRS and SRW wheat farina, while a slight increase was observed in the case of durum semolina. SPI-1 showed an improving effect on dough stability of all the samples while SPI-2 showed an adverse effect on HRS, SRW wheat farina, and a slight improvement of semolina dough stability. The remainder of the high-protein products showed fewer or similar differences on dough stability when added at the 10% level. High-protein materials at different concentrations had a slight effect on the peak time of semolina dough (Table II), while marked changes were noticed with the HRS and SRW wheat farina (Table III).

Departure time is an important factor in dough rheology testing. As this value increases it indicates a stronger flour. Semolina dough, because of its weak, plastic structure, usually has a short departure time varying between 3–5 min.

High-protein samples of soy and cottonseed, when added at the 5, 10, and 20% level, increased the departure time of semolina dough considerably. When 10% of SPI-2 was

Table IV. Quality of Spaghetti Made with 10% Soy or Cottonseed High-Protein Materials

sample	total protein,[a] %	spaghetti color score	cooked weight, g	cooking loss, %	firmness score, g·cm
		durum wheat semolina			
semolina (control)	12.2	8.5	37.7	5.6	4.8
SPI-2	20.1	8.0	33.4	5.0	6.3
SPI-1	19.1	8.0	33.2	5.6	7.7
SPI-3	18.6	8.0	31.1	5.9	7.8
SPC	17.1	8.0	35.7	5.5	4.5
NSF	15.9	6.0	34.0	7.8	4.5
CSM	16.6	4.0	37.2	7.7	5.5
		HRS wheat farina			
farina (control)	13.5	5.0	33.4	4.4	5.3
SPI-2	21.3	5.0	32.1	5.4	8.6
SPI-1	20.2	4.5	31.1	5.6	9.6
SPI-3	19.8	4.5	29.5	5.4	9.1
SPC	18.2	4.5	33.7	6.0	5.3
NSF	17.1	4.5	33.7	7.0	6.9
CSM	17.8	3.0	35.8	6.4	6.0
		SRW wheat farina			
farina (control)	8.6	4.5	35.8	4.8	5.0
SPI-2	16.8	5.0	36.5	6.3	5.4
SPI-1	15.7	5.0	32.7	6.9	7.6
SPI-3	15.3	5.0	32.4	6.7	6.9
SPC	13.7	4.5	36.9	7.4	4.0
NSF	17.6	5.5	35.9	7.6	4.9
CSM	13.3	4.0	35.5	7.2	6.6

[a] 14% moisture basis, 5.7 and 6.25 factor was used for wheat and soy products, respectively.

added to both HRS and SRW farina, a decrease in departure time was noticed, while the reverse effect was observed on semolina dough.

Mechanical tolerance index (MTI) is an indication of flour strength. The higher the value the weaker the flour (Shuey et al., 1972). Semolina doughs are considered weak doughs since they have higher MTI values than HRS or SRW wheat dough. High-protein materials at all levels decreased the MTI value of semolina dough (Table II). At the 10% level the most beneficial effect on SRW and HRS wheat farina was noticed when SPC and SPI-3 were added, respectively (Table III).

Spaghetti Processing. Table IV presents the quality data for spaghetti processed from durum wheat semolina, HRS wheat farina, and SRW wheat farina with the addition of 10% high-protein materials. Spaghetti processed from 100% durum semolina gave the best overall quality. Color is a major quality factor of the macaroni manufacturing industry in the U.S. Spaghetti made from 100% semolina showed the highest color score. When high-protein materials were used with semolina to produce spaghetti, the color was slightly decreased except for NSF and CSM which caused a marked decrease in spaghetti color. When HRS wheat farina was used in place of semolina, spaghetti color was decreased in most cases except the SPI-2 which gave a color score equal to the control farina. The addition of high-protein materials to SRW wheat farina resulted in color scores equal to the control or better except for CSM which decreased the color of the spaghetti produced.

The cooking quality of spaghetti made from durum wheat semolina with different high-protein materials generally was acceptable. Samples made from 100% semolina showed superior quality over all the samples. Cooked weight of spaghetti made from 100% semolina decreased markedly by the addition of high-protein materials to semolina except for CSM. In the case of HRS farina, a slight decrease in cooked weight was observed except with CSM which increased the cooked weight of the sample. SPI-1 and SPI-3 decreased the cooked weight of spaghetti made with SRW. In all cases SPI-3 produced a decrease in spaghetti cooked weight, which may be due to a high water-soluble protein fraction in the soy protein resulting in higher cooking losses.

Cooking loss of spaghetti made from semolina, NSF, and CSM was slightly higher than the 100% semolina sample. Whey soy or cottonseed high-protein products were added to HRS wheat or SRW wheat farinas, a marked increase in cooking loss was noticed in all cases.

When high-protein materials were added to semolina they increased in spaghetti firmness except for SPC and NSF which had values about equal to the control. Significant increases in spaghetti firmness was noticed when high-protein materials were added to HRS wheat and SRW wheat farinas except with SPC which reduced the firmness of the SRW sample slightly. Values over 7.0 may be considered too tough or "rubbery". Therefore, the addition of SPI-1, -2, and -3 to HRS wheat farina considerably reduced the cooking quality of its spaghetti.

No significant relationships were observed between the dough rheology of semolina, HRS, and SRW wheat farinas and spaghetti cooking quality. Although some of the high-protein materials improved the dough rheology of semolina, the cooking quality of the final spaghetti made from composites was not improved when compared with the control.

The results indicate that high-protein spaghetti with lower color scores could be made from durum wheat semolina, HRS or SRW wheat farina with added soy, or cottonseed high-protein materials. Spaghetti made from durum wheat semolina and different high-protein materials, in general, showed better overall quality when compared to spaghetti made with HRS wheat or SRW wheat farinas.

LITERATURE CITED

Bloksma, A. H., in "Wheat Chemistry and Technology", Vol. III, Pomeranz, Y., Ed., American Association of Cereal Chemists, St. Paul, Minn., 1971, pp 523–584.

Dick, J. W., Walsh, D. E., Gilles, K. A., *Cereal Chem.* **51**, 180 (1974).

Glucklich, J., Shelef, L., *Cereal Chem.* **39**, 242 (1962).

Harris, R. H., Sibbitt, L. D., *Cereal Chem.* **18**, 388 (1942).

Hummel, C., "Macaroni Products", Food Trade Press, London, 1966, pp 66–92.
Pyler, E. J., "Baking Science and Technology", Vol. II, Siebel Publishing Co., Chicago, Ill., 1973, pp 835–897.
Seyam, A., Shuey, W. C., Maneval, R. D., Walsh, D. E. *Proc. Natl. Conf. Wheat Util. Res.*, 8th 101 (1973).
Shuey, W. C., Locken, L., Loska, S., in the "Farinograph Handbook", 2nd ed, Shuey, W. C., Ed., American Association of Cereal Chemists, St. Paul, Minn., 1972, pp 47–48.
Walsh, D. E., Youngs, V. L., Gilles, K. A., *Cereal Chem.* **47**, 119 (1970).

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Qualitative and Quantitative Analyses of the Essential Oils of Red and Ladino White Clovers

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The essential oils of red and Ladino white clovers were respectively isolated by steam distillation of the fresh grasses with yields of 0.0005 and 0.0032%. The essential oils were analyzed by combined gas chromatography–mass spectrometry and gas chromatographic comparison with authentic specimens, directly or after the fractionation to each functional group, to identify, respectively, about 80 compounds consisting of acids, phenol, aldehydes, ketones, alcohols, esters, hydrocarbons, and miscellaneous. Both essential oils showed some differences in the components of aldehydes, alcohols, and esters. Quantitative analyses were further carried out on the essential oils: red clover was rich in hydrocarbons, while Ladino white clover was rich in alcohols and esters.

Under the assumption that the aromas of forages might have some connection with the palatability or herbage intake of domestic animals, investigations of the aromatic constituents of forage crops were undertaken. In the present work, the essential oils of red and Ladino white (ladino) clovers, which are leguminous pasture plants, were analyzed by means of combined gas chromatography–mass spectrometry and gas chromatographic comparison with authentic specimens, in connection with the previous papers (Kami, 1975, 1977) on the analyses of the essential oils of Hybridsorgo and Sudangrass, which are gramineous forage plants.

Since the different clovers (*Trifolium*) are very important for the nutrition of domestic animals, many agricultural species of clovers are widely cultivated in the world. In the southwestern warm district of Japan, red clover (*Tr. pratense* L.) and ladino clover (*Tr. repens* L., giant or mammoth white clover) are especially cultivated as the major roughage of dairy cattle. This is due to the adaptation to the climate and soil of this district, to the suitability for the mixed sowing with forage grasses, and to the superiority in their palatability for dairy cattle.

EXPERIMENTAL SECTION

Materials. Red clover (Kenland-early variety) and ladino clover were cultivated on a farm of the Faculty of Fisheries and Animal Husbandry, Hiroshima University. The former was harvested in May 1971 and the latter in July 1974 by mower. The harvest times corresponded to the first flowering stage of each clover.

Isolation of the Essential Oils. The fresh crops (red, 260 kg; ladino, 170 kg) were, respectively, steam distilled in 26–30-kg lots under 0.8 kg/cm^2 pressure for 1 h using a boiler and sterilization kettle in a cannery of the Faculty of Fisheries and Animal Husbandry, Hiroshima University. The distillates were collected into a series of three traps cooled with water, ice–water, and dry ice–methanol; in total, red clover and ladino clover gave, respectively, about 130 and 100 L of cloudy aqueous liquids in the first trap, 26.2 and 19.2 g of colorless aqueous liquids in the second trap, and 15.4 and 0.5 g of colorless aqueous liquids in the third trap. Each cloudy aqueous liquid collected in the water-cooled trap was saturated with sodium chloride and extracted twice with distilled diethyl ether to yield a dark-brown essential oil with an unpleasant bitter odor (red, 1.25 g, pH 2.0; ladino, 5.4 g, pH 2.0). These essential oils were stored in sealed tubes at 3 °C, as were the aqueous condensates from the second and third traps of both clovers.

Fractionation of the Essential Oils. A portion (red, 670 mg; ladino, 2990 mg) of each essential oil was sequentially shaken with 10% sodium carbonate, 3% sodium hydroxide, and 3% hydrochloric acid aqueous solutions to separate it into acid (brown viscous; red, 30 mg; ladino, 384 mg), phenolic (orange viscous; red, 51 mg; ladino, 65 mg), and basic (drab viscous; red, 24 mg; ladino, 92 mg) fractions (Kami, 1975). Among them, the acid fraction was further converted to the methyl esters with diazomethane (Vorbeck et al., 1961). The remaining neutral oil layer (red, 345 mg; ladino, 1821 mg) was extracted in *n*-pentane and then diethyl ether with silicic acid to separate it into nonpolar (white crystal; red, 19 mg; ladino, 186 mg) and polar (yellow brown liquid; red, 105 mg; ladino, 907 mg) fractions (kami, 1977).

Analyses of the Essential Oils. In the beginning, the unfractionated essential oils of both clovers were injected to a combined apparatus of a Hitachi K53 gas chromatograph with a Carbowax 20M column and a Hitachi RMU-6E mass spectrometer, and the mass spectra of all components were taken (GC–MS). In addition, the fractions of red clover oil, except for the basic fraction, were

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