Physical, Mechanical, and Thermal Properties of Water-Blown Rigid Polyurethane Foam Containing Soy Protein Isolate[1]

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ABSTRACT

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Soy protein isolate (SPI) was incorporated into water-blown rigid polyurethane foam. The SPI and initial water content varied from 0 to 40% and 5 to 7% of polyether polyol, respectively. Foams containing SPI exhibited thermal conductivity values similar to or slightly higher than foams containing no SPI. The density, compressive strength, compressive modulus, and dimensional stability of foams with or without SPI decreased as the initial water content increased. Adding SPI up to the 20% level at 5% initial water content provided water-blown rigid polyurethane foams with similar or improved strength values and dimensional stability under thermal and humid aging.

Rigid polyurethane foams are all around us, making a great contribution to our daily lives—from foam insulation to packaging. Utilization of these foams continues to grow at a rapid pace throughout the world. This growth can be attributed to the light weight, excellent strength-weight ratio, superior insulating abilities, and energy-absorbing performance (including shock, vibration, and sound) of the foams (Klempner and Frisch 1991).

Recently, the use of renewable resources in the polyurethane industry has attracted the attention of many researchers (Bennett et al 1967; Cunningham et al 1991, 1992a,b; Yoshida et al 1987, 1990; Reimann et al 1990; Saraf et al 1985). These researchers have reported success with the incorporation of polysaccharides into polyurethane systems. In addition, several patents covering the utilization of plant components in the preparation of polyurethane foams have been filed (Boggs 1959, Dosmann and Steel 1961, Otey 1968, Hostettler 1979, Kennedy 1985). Advantages such as increased strength, improved flame resistance, and enanced biodegradability in incorporating carbohydrate into polyurethanes have been reported by Donnelly (1991). These studies from the literature focused mainly on the incorporation of carbohydrate into the polyurethane matrix. Less attention has been directed to protein-based materials.

Under a recent international agreement (Montreal Protocol), the use and production of chlorofluorocarbon (CFC) blowing agents is restricted and is being phased out because chlorofluorocarbons are harmful to the Earth's ozone layer (Kupchella and Hyland 1989, Molina and Rowland 1974). Thus, the objectives of this study were to investigate the effects of water content and the percentage of the soy protein isolate (SPI) on water-blown rigid polyurethane foam. In addition, foam properties such as density, compressive strength, compressive modulus, apparent thermal conductivity, and dimensional stability under thermal and humid aging that are important in determining their suitability for most foam applications (Cunningham et al 1991) are evaluated.

MATERIALS AND METHODS

Materials

The proximate composition of soy protein isolate purchased from ADM Protein Specialties Company (Decatur, IL) is shown in Table I. Other components used in the foam formulation include polymeric isocyanate (PAPI 27, Dow Chemical Co., Midland, MI), polyether polyol (POLY-G 75-442, Olin Corp., Stamford, CT), catalyst (tertiary amine, Texacat ZF-10, Texaco Chemical Co., Houston, TX), crosslinking agent (triethanolamine, Aldrich Chemical Co., Milwaukee, WI), surfactant (L-5440, Union Carbide Corp., Danbury, CT), and blowing agent (distilled water).

Foam Preparation

A standard mixing procedure for making foams (Bailey and Critchfield 1981) was used in this study. This procedure involves intensive mixing using a commercial drill press (Colcord-Wright, St. Louis, MO) fitted with a 25.4-cm shaft with a 5-cm impeller arranged to turn at 1,845 and 3,450 rpm. Polyether polyol, tertiary amine, isolated soybean protein, crosslinking agent, and blowing agent (component A), as shown in Table II, were sequentially weighed by a balance and added into a 0.946-L (1 quart) disposable paperboard container fitted with a steel frame with four baffles next to the container wall and mixed at 3,450 rpm for 60 sec. Then stirring was stopped, allowing the mix to degas. After 15 sec, polymeric isocyanate (component B) was rapidly added and stirring continued for another 15 sec at the same speed. Finally, the reacting mixtures were poured immediately into wooden boxes (200 × 200 × 100 mm) and allowed to rise at ambient conditions. Foams were removed from boxes after 1 hr and allowed to cure at room temperature (23°C) for one week before test specimens were cut with a band saw. Two replicate foams were prepared with each formulation.

TABLE I
Product Description of PRO-FAM S955 Soy Protein Isolate[a]

Component	%
Protein[b]	90.0
Ash	5.5
Fat (P.E. extract)	0.5
Moisture content	6.0
pH	5.6–6.2
Calcium	0.16
Sodium	1.00
Potassium	0.15
Phosphorus	0.80
Magnesium	0.09
Iron	0.01
Zinc, ppm	75
Copper, ppm	7

[a] Adapted from ADM (1992).
[b] (N × 6.25, moisture-free basis)

Experimental Design

The effects of the following variables in the foam formulation on the properties of water-blown rigid polyurethane foams were studied: 1) concentrations of SPI in parts per hundred polyether polyol weight (0, 10, 20, 30, and 40); and 2) initial water contents in parts per hundred polyether polyol weight (5, 6, and 7). Other factors in foam formulation such as catalyst, surfactant, crosslinking agent, and isocyanate index were fixed.

The catalyst (tertiary amine) serves to speed up the reaction of isocyanate and polyol. The crosslinking agent forms a bridge between individual polymers or increases the level of covalent bonding in polyurethane foam matrix. The function of the surfactant is to aid in foam-forming processes and to avoid foam collapse and foam splitting. Therefore, concentrations of the catalyst, crosslinking agent, and surfactant in the foam formulation were established first in a preliminary study to assure that all foam products could be prepared within a few minutes without apparent shrinkage and distortion.

Thus, this experiment was a 5 × 3 factorial design. Table II shows foam formulation for water-blown rigid polyurethane foam. The amount of isocyanate added in each formulation was based on total hydroxyl content of the polyether polyol, triethanolamine, and water, which includes water originally present in the isolated soybean protein. The amount of water and polymeric isocyanate were varied to maintain the same isocyanate index in each formulation, as shown in Table III.

TABLE II
Formulations for Water-Blown Rigid Polyurethane Foam Extended with Soy Protein Isolate

Ingredients	Parts by Weight
Component A	
Polyol	70
Catalyst	0.5
Soy protein isolate	0, 7, 14, 21, 28
Surfactant	2.0
Crosslinking agent	0.5
Blowing agent	3.5, 4.2, 4.9
Component B	
Polymeric MDI[a]	150, 162, 174

[a] Isocyanate to attain index of 115, defined as actual amount of isocyanate used over theoretical amount of isocyanate required, multiplied by 100.

TABLE III
Polymeric Isocyanate and Water Added to Foam Formulation at Different Levels of Soy Protein Isolate (SPI)

Initial Water Content (%)	Level of SPI Addition to Foam Formulation (%)	Added Water (g)
5[a]	0	3.50
	10	3.08
	20	2.66
	30	2.24
	40	1.82
6[b]	0	4.20
	10	3.78
	20	3.36
	30	2.94
	40	2.52
7[c]	0	4.90
	10	4.48
	20	4.06
	30	3.64
	40	3.22

[a] Containing 150 g of polymeric isocyanate.
[b] Containing 162 g of polymeric isocyanate.
[c] Containing 174 g of polymeric isocyanate.

Foam Property Measurements

Densities of the samples were determined using American Society for Testing and Materials (ASTM) Procedure D 1622-88. Compressive strength and modulus were measured on an Instron universal testing machine, model 1132 (Instron Corporation, Canton, MA) with a data acquisition system, using ASTM procedure D 1621-73 (reapproved 1979). The voltage versus time output was converted into digitized load versus deformation relationships. The compressive strength was calculated by dividing the load by the initial cross-sectional area of the specimen. The compressive modulus was calculated as the highest ratio of stress and strain. At least six specimens were tested from each direction (parallel and perpendicular to foam rise), and the average values were reported. Apparent thermal conductivity of the samples was determined using ASTM C 518-91 heat flow meter method with a Holometrix model Rapid-k heat flow meter instrument (Holometrix, Inc., Bedford, MA). The dimensional stability test including thermal and humid aging was tested according to ASTM D 2126-87. A benchtop temperature-humidity chamber with Versatenn (Tenney Engineering, Inc., Union, NJ) was used to conduct this test. The volume and weight changes of samples were calculated, expressed as the percentage of the initial volume and weight. The average from three samples was reported.

Scanning Electron Microscopy (SEM)

The samples for SEM were dried overnight in a vacuum oven at 65°C to reduce moisture content and then cut using a razor blade. Each specimen was fixed on the aluminum stub with a copper tape and was coated with gold-palladium by an SEM sputter coater (model E5100, Polaron Instruments Inc., Cambridge, MA). A 2.5-kV voltage and a 20-mA current were applied for 2 min to deposit a conductive layer of 30 nm in thickness over the specimen. The specimen was examined with a JEOL scanning electron microscope (model JSM-35, Japan) at 20 kV. Photographs were taken using Polaroid 55 P/N film (Polaroid Corp., Cambridge, MA).

RESULTS AND DISCUSSION

Density

Figure 1 shows the effect of SPI and blowing agent (initial water content) on the density of polyurethane foams. As shown, the foam density increased with increasing weight percentage of SPI and decreased with increasing initial water content. There was no interaction between the effect of SPI and the effect of initial water
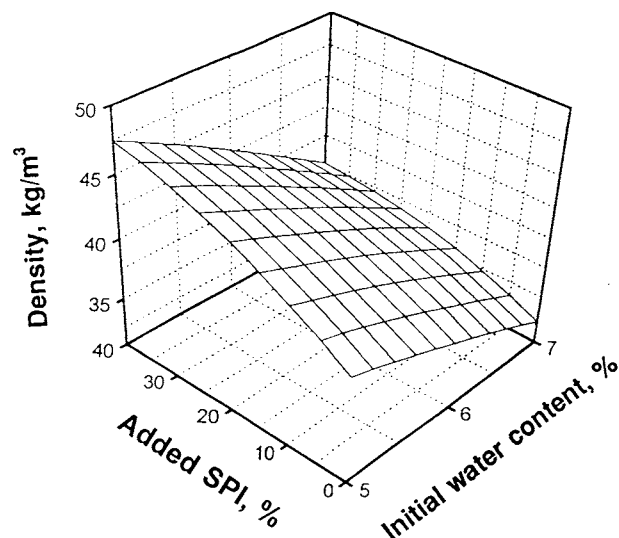

Fig. 1. Effect of initial water content and soy protein isolate (SPI) percentage on foam density.

content on the foam density ($P < 0.05$).

The density of a plastic foam is governed by the weight and volume of the plastics making up the matrix of the foam and the gases trapped in the foam cells. The plastic phase composition includes polyol, isocyanate, and all additives such as surface active agents, stabilizers, crosslinking agents, SPI, or processing aids (catalysts). The gas phase composition includes carbon dioxide, generated from the chemical reaction between the blowing agent (water) and the components of the foam formulation (isocyanate), and air, which is either introduced into the reaction vessel during the foaming process or diffuses into the cells during the aging process. When the initial water content was set at 5, 6, or 7%, each foam formulation had the same amount of every component with the exception of the weight percentage of SPI. Increasing the amount of SPI in the foam formulation increased the foam weight. On the other hand, the added SPI contributed very little to the foam volume. Therefore, as expected, the foam density increased with increasing weight percentage of SPI in the formulation.

Water acts as a blowing agent that reacts with the isocyanate in the foam formulation and produces carbon dioxide. As a result, increasing the water content should generate more gaseous carbon dioxide. Because the foam was more expanded and yet the foam weight remained essentially the same, the foam density was reduced. Similar results were reported by Cunningham et al (1991) for polyurethane foams extended with corn flour.

Compressive Strength

Although rigid polyurethane foams are materials of low density, they possess a considerable mechanical strength. The compressive strength of a foam is defined as the maximum compressive stress level the foam can withstand for a very short time at a fixed point in the compression loading cycle (Frisch and Saunders 1972). Figure 2 shows the stress-strain curves at four levels of SPI addition and 5% initial water content based on the percentage of polyether polyol under compressive loads where the specimen was compressed parallel to the foam rise direction. The control foam and foam containing SPI exhibited a yield point before 10% deformation, but in the latter cases, the yield point was not evident, because the curves just flattened or fluctuated slightly. Using carbohydrates derived from corn to substitute partially for polyether polyol in rigid polyurethane foam formulation, Cunningham et al (1992) also reported yield points before 10% de-
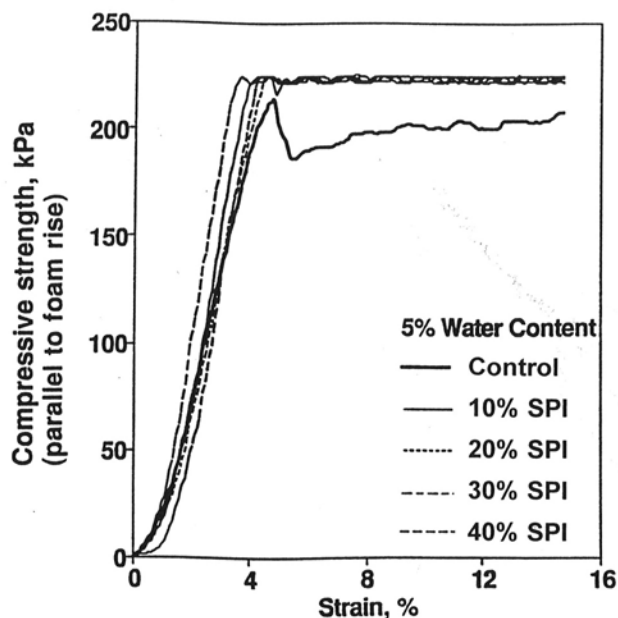
formation. The stress-strain curves for foams containing 6 and 7% initial water content behaved similarly to the foams containing 5% initial water content but with lower compressive strength.

The response surface of the compressive strength (parallel to foam rise direction) as a function of SPI percentage and initial water content is shown in Figure 3. An increase in initial water content decreased compressive strength. This is a commonly observed phenomenon in many cellular foam systems (Oertel 1985). Increasing the initial water content expanded the foam volume. This would weaken the foam structure due to thinner foam cell walls and larger foam cells. An increase in SPI up to 20% caused an increase in the compressive strength. Further increase resulted in a decrease in the compressive strength. It appears that SPI, up to 20% addition, might have reacted with the isocyanate and other components in the foam formulation and contributed to the strength of the foam structure. Further addition of SPI above 20% might have exhausted the availability of the isocyanate to interact
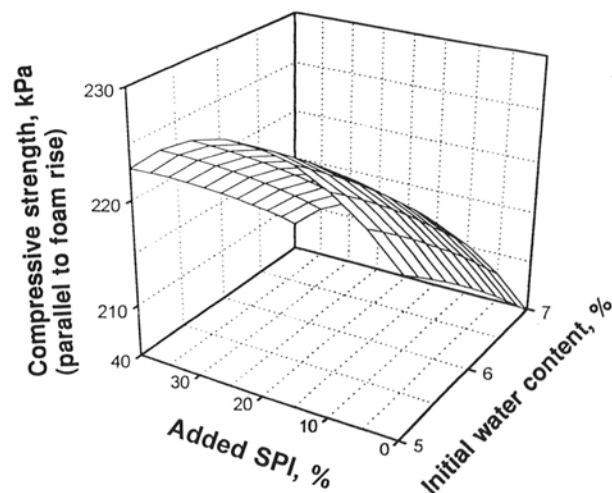
Fig. 3. Effect of initial water content and soy protein isolate (SPI) percentage on foam compressive strength (parallel to foam rise).

Fig. 2. Compressive strength-strain curves for foams with or without soy protein isolate (SPI) at 5% initial water content (parallel to foam rise).
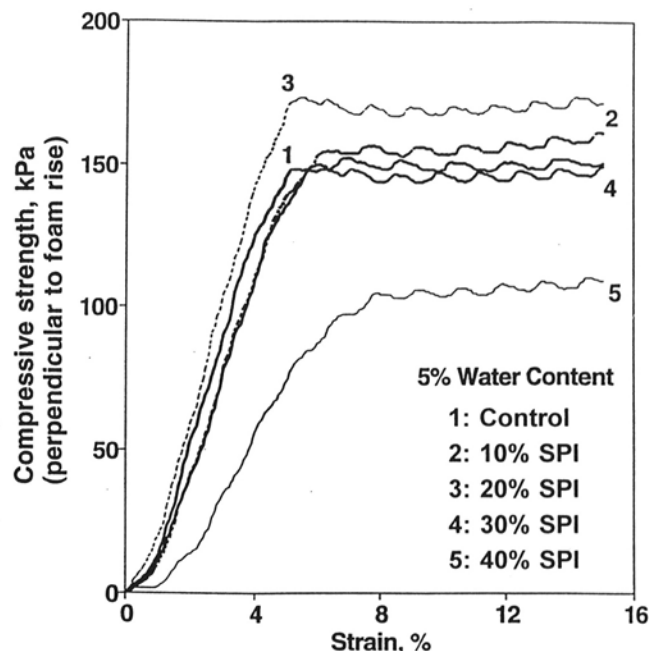
Fig. 4. Compressive strength-strain curves for foams with or without soy protein isolate (SPI) at 5% initial water content (perpendicular to foam rise).

with soybean protein. Thus, the additional SPI may have only acted as a filler or extender in the foam; it interfered with the reaction between isocyanate and water and weakened the foam structure.

The stress-strain curves for foams containing 5% initial water content under compressive loads where the test sample was compressed perpendicularly to the foam rise direction is shown in
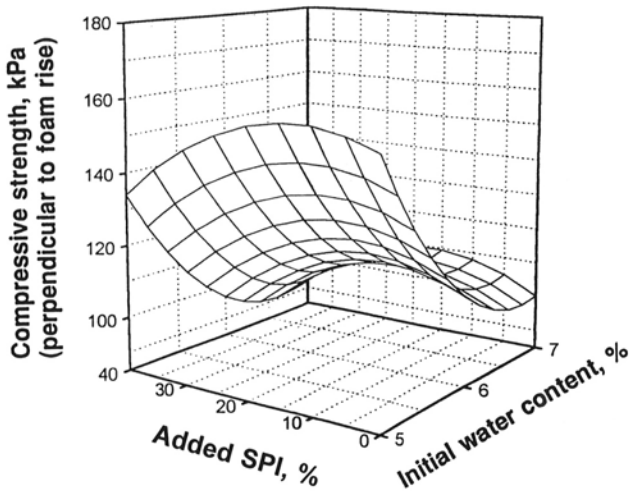

Fig. 5. Effect of initial water content and soy protein isolate (SPI) percentage on foam compressive strength (perpendicular to foam rise)
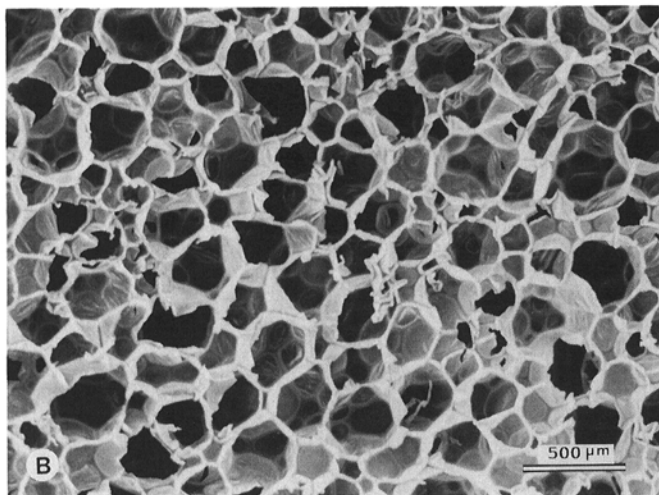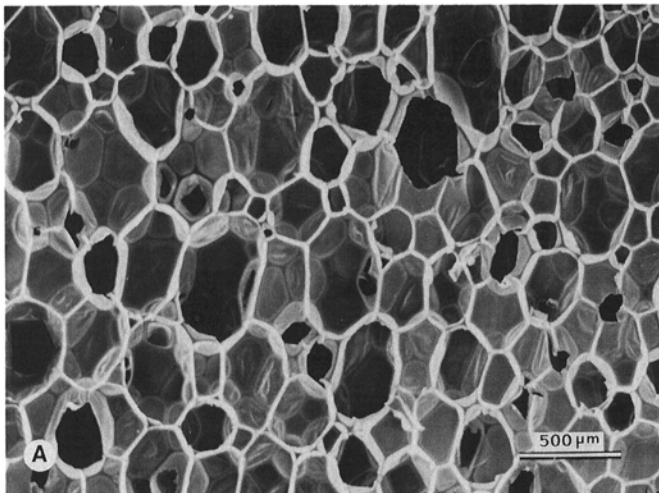

Fig. 6. Scanning electron micrographs illustrating foam cell orientation. **A,** Elongated cells parallel to foam rise direction. **B,** Round cells perpendicular to foam rise direction.

Figure 4. None of the foams exhibited noticeable yield points. Similar stress-strain curves were obtained for foams containing 6 and 7% initial water content (data not shown). The response surface of the compressive strength (perpendicular to the foam rise direction) as a function of initial water content and SPI percentage is shown in Figure 5. Again, similar to the results for samples taken from parallel to the foam direction, the compressive strength of these foams decreased with increasing initial water content but increased with increasing SPI percentage up to 20% and then decreased.

It is interesting to note that the compressive strength of the polyurethane foam samples in the parallel to the foam rise was about 50% higher than those perpendicular to the foam rise (Figs. 3 and 5). For polymeric foams made by pouring the reaction mixture into a mold, the foam's cellular structure contains some degree of orientation in the direction of foaming, resulting in oblong cells. This has already been referred to in the literature (Benning 1967). Scanning electron micrographs of a typical foam sample (6% initial water content and 20% SPI) shown in Figure 6 illustrate this phenomenon. Figure 6A was taken in the direction perpendicular to foam rise and contains elongated cells, while 6B was taken in the foam rise direction and contains round cells. Thus, foams had more elongated cells in the direction of foam
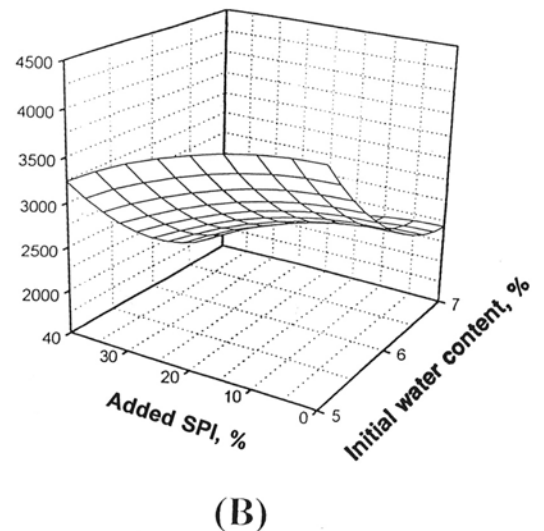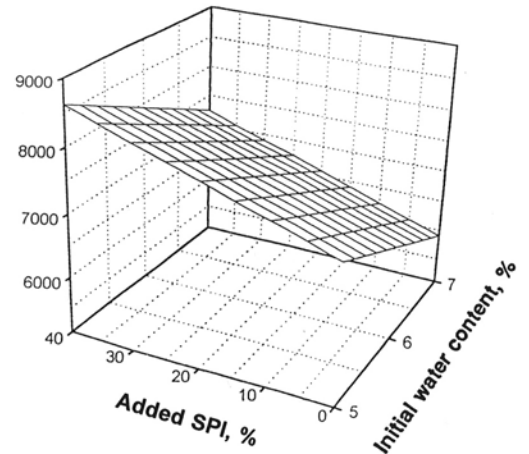

(B)

Fig. 7. Effect of initial water content and soy protein isolate (SPI) percentage on foam compressive modulus parallel to foam rise (**A**) and perpendicular to foam rise (**B**).

rise when compared to those in the plane normal to it. In other words, foams were oriented in the direction of foaming, due to the surrounding restraints (mold walls). These oriented cells buckled when subjected to compression force parallel to the foam rise direction but flexed from force perpendicular to the foam rise direction. Because buckling requires much more stress than does flexing (Shutov 1982, Ashby 1983), the compressive strength was higher when the load was applied in the oriented or foam rise direction. This finding is in agreement with Benning's (1967) work on polystyrene foams.

Compressive Modulus

The compressive modulus of a material, a measure of its rigidity, is defined as the ratio of stress to strain in a material loaded below its yield point (Burnswick 1989). The compressive moduli of rigid foams reported is the maximum slope of the stress-strain curve. Its value is an index of the hardness of a material. The higher the compressive modulus is, the harder the material. A higher slope in the stress-strain curve indicates a larger increase in stress is required for the same amount of deformation.

The response surface of the compressive modulus (parallel to the foam rise direction) as a function of initial water content and SPI percentage is shown in Figure 7A. An increase in the initial water content decreased the compressive modulus. However, an increase in the SPI content increased the compressive modulus. Figure 7B shows the effect of the initial water content and SPI percentage on the foam's compressive modulus (perpendicular to the foam rise direction). An increase in the initial water content also decreased the compressive modulus. An increase in the SPI content did not affect the compressive modulus up to 20% addition and then decreased. These trends were essentially similar to those of compressive strengths except the compressive modulus (parallel to foam rise direction) continued to increase when the SPI content exceeded 20%.

Like the compressive strength, the cell orientation would affect the compressive modulus value as reported by Lederman (1971). Thus, the magnitude of the compressive modulus in the parallel to foam rise direction was greater that in the perpendicular to foam rise direction.

Apparent Thermal Conductivity

Rigid polyurethane foams are remarkable for their excellent thermal insulation due to their low apparent thermal conductivity. They have been recognized all over the world as the most efficient insulation material commercially available since their introduction (Cunningham and Sparrow 1986). Apparent thermal conductivity (k-value) of a foam is defined as the rate of heat flux per unit thickness of the foam for unit difference in temperature. The insulating capacity of a foam increases as its k-value decreases. The effects of the initial water content and SPI percentage on a foams' apparent thermal conductivity are shown in Figure 8. An increase in the SPI percentage increased the apparent thermal conductivity. This was caused by the increase in the polymer phase content as the foam density increased and the thermal conductivity of the polymer phase (0.262 W/mK) (Glickman 1991) was 10 times or more of the gas phase (air, 0.026 W/mK and CO_2, 0.016 W/mK) in the foam. However, all foams extended with SPI had k-values within 0.5-7% of the control's k-value. Statistical analysis using LSD rules showed no significant difference in the k-values between the control foam and the foams containing equal or less than 20% SPI.

The k-value increased with increasing initial water content up to 6% and then slightly decreased. This was different from the effect of SPI on the apparent thermal conductivity, where increasing SPI increased both polyurethane foam's density and apparent thermal conductivity. Because foam's density decreased with increasing water content, the initial increase in the k-value might have been caused by increased convection heat transfer due to

larger foam cells, resulting from a greater foam volume. As the foam density continued to decrease due to increasing initial water content beyond 6%, the effect of lower polymer phase content due to lower foam density became more pronounced and hence the k-value decreased.

Dimensional Stability

Rigid polyurethane foams, due to their ability to be molded to size, are particularly suitable for structural or foamed-in-place applications where a complex shape is involved. In general, foams of this type do not allow for preconditioning prior to installation. The dimensional stability of rigid polyurethane foams, in situations where they are subjected to accelerated aging at a standard temperature and relative humidity, is the most important property to be carefully considered, especially for low-density foams.

During thermal aging (70°C and 5% rh), all extended foams had higher weight loss than did the control foams when the water content was kept constant (Table IV). The weight losses for all foams never exceeded 3%, however. The weight loss increased with increasing aging period and with increasing weight percentage of SPI. The changes in foams' volume during thermal aging were also increased as the aging period increased, but were less than 2% for all foams. It is interesting to note that even though all foams lost weight during thermal aging, their volume increased. Similar results were also reported by Cunningham et al (1991) for polyurethane foams extended with corn flour.

The diffusion of air into the foam cells as well as the diffusion of carbon dioxide out of the cells were accelerated at a higher temperature. Because the pressure inside the cell was different from atmospheric, the developed stress would cause the foam to deform. Although some variations in volume change were observed during the aging period for the control foam and the SPI extended foams, foams containing up to 20% SPI generally changed less in volume than that for the control foam and for foams at a higher level of isolated soybean protein addition (30% or 40%). As shown in Figures 5 and 7B, foams with 20% SPI had a greater compressive strength and compressive modulus at perpendicular to the foam rise direction than other levels of SPI addition. Thus, these foams were more rigid and changed less in volume when subjected to thermal aging.

During humid aging (38°C and 97% rh), weight gains of foams increased with SPI and decreased with initial water content (Table V). The weight gain increased as the weight percentage of SPI increased was probably due to a greater water absorption capacity
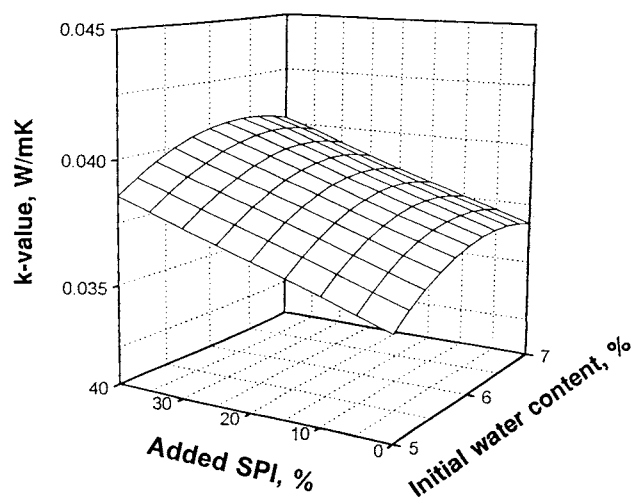

Fig. 8. Effect of initial water content and soy protein isolate (SPI) percentage on foam k-value.

TABLE IV
Effect of Thermal Aging on Dimensional Stability of Water-Blown Rigid Polyurethane Foams Extended with Soy Protein Isolate (SPI) at 70°C and 5% rh

Initial Water Content[b]	Added SPI, %[a]				
	0	10	20	30	40
5% initial water content					
Weight change, %					
Day 1	1.37	−1.58	−2.00	−2.01	−2.02
Day 7	−1.50	−2.21	−2.37	−2.29	−2.75
Day 14	−1.97	−2.49	−2.64	−2.97	−2.89
Volume change, %					
Day 1	0.34	0.36	0.0	0.35	0.35
Day 7	1.00	1.07	1.02	0.02	1.87
Day 14	0.51	0.39	0.0	0.18	1.04
6% initial water content					
Weight change, %					
Day 1	−1.21	−1.55	−1.94	−1.77	−1.84
Day 7	−1.56	−1.95	−1.94	−2.10	−2.09
Day 14	−1.95	−2.44	−2.44	−2.64	−2.62
Volume change, %					
Day 1	0.45	0.10	0.34	0.44	0.54
Day 7	0.76	0.51	0.66	0.98	0.74
Day 14	0.96	0.71	0.66	0.98	1.40
7% initial water content					
Weight change, %					
Day 1	−0.68	−1.00	−1.23	−1.23	−1.53
Day 7	−1.51	−2.08	−2.19	−2.34	−2.32
Day 14	−1.79	−2.04	−1.99	−2.04	−2.14
Volume change, %					
Day 1	0.85	0.22	0.43	0.11	0.44
Day 7	1.24	0.63	0.43	1.42	0.84
Day 14	1.35	1.22	1.33	1.62	1.24

[a] Percent of isolated soybean protein is based on weight of polyether polyol.

[b] Foams containing 5, 6, and 7% initial water content, respectively, based on weight of polyether polyol.

of SPI than the polyurethane foam polymer phase. On the other hand, as the initial water content increased the foam was more expanded, the water absorption sites in the foam became less and hence the weight gain reduced with increasing initial water content. The changes in weight were less than 8% for all foams during humid aging (Table V).

Benning (1969) reported that the rigid polyurethane foam will absorb water to equilibrate with the water vapor in a surrounding atmosphere (97% rh in this study). This sorption will result in changes in dimensions, weight, and physical properties. Traeger (1967) showed that the rigid polyurethane foams contain no moisture immediately after preparation. However, the dry foams do pick up water rapidly, and small samples may absorb significant quantities of water during weighing.

The quantity of moisture absorbed depends on the composition of the foam. In this study, the foam containing 40% SPI had the greatest weight gain (up to 7.24%). In addition, the amount of absorbed water also depends on whether the cell structure of a foam is closed or open and whether the foam contains skin or not. If the molded foam has continuous foam skins, the rate of water diffusion into the foam will be greatly reduced. In this study, the foams were cut by a band saw into small pieces. The surface of each piece was destroyed and the continuous skin surfaces removed. Klempner and Frisch (1991) indicated this mechanical trapping in cut or ruptured cells will greater enhance the water vapor diffusion rate into the foam polymer.

As the initial water content increased, the change in volume increased during humid aging (Table V). This observation is in agreement with that of Hilado (1967). He found that an increase in the foam density decreased the foam's volume change. Frisch and Saunders (1972) also indicated that there are several reasons,

including the molecular structure of the polymer, its modulus-temperature relationship, the type and pressure of blowing agent remaining in the foam cells, and the foam density, which affect the dimensional stability of a foam.

With respect to the effects of added SPI, some variations in volume change during humid aging were observed. However, it seemed that the minimum foam volume change occurred at around 10% SPI level instead of 20% as observed during thermal aging (Table V). Although foams with 20% SPI had a higher compressive strength and compressive modulus (Figs. 5 and 7B) than foams with 10% SPI, foams with a higher SPI level also tended to absorb more water during humid aging, which could plasticize polyurethane foams and weakened their structure. Therefore, foams with 10% SPI might have a higher overall dimensional stability than those with 20% SPI during humid aging.

The increase in volume at a high relative humidity (humid aging) was higher than that under a dry condition (thermal aging) due to the absorption of moisture, which plasticized the polyurethane foam (Tables IV and V). Similar results were reported by Hilado (1967). The dimensional stability (in terms of volume change) and performance characteristics of a rigid polyurethane foam are significantly affected by the conditions of the testing environment. A combination of high temperature and high humidity is more likely to threaten the integrity and performance of the rigid polyurethane foam than high temperature or high humidity alone.

In conclusion, addition of SPI up to 20% level appears to impart water-blown rigid polyurethane foams with similar or improved strength values, insulation values, and dimensional stability. Further study is needed to demonstrate their suitability for specific applications.

TABLE V
**Effect of Humid Aging on Dimensional Stability of Water-Blown Rigid Polyurethane Foams
Extended with Soy Protein Isolate (SPI) at 38°C and 97% rh**

Initial Water Content[b]	Added SPI, %[a]				
	0	10	20	30	40
5% initial water content					
Weight change, %					
Day 1	1.55	1.86	2.58	3.77	4.19
Day 7	1.99	3.78	4.30	5.91	7.24
Day 14	1.48	2.96	3.54	4.84	6.67
Volume change, %					
Day 1	2.06	1.68	2.24	1.73	1.51
Day 7	2.41	2.19	2.59	2.72	1.69
Day 14	3.27	1.52	3.10	2.40	2.21
6% initial water content					
Weight change, %					
Day 1	1.38	1.13	2.82	3.13	3.74
Day 7	1.60	3.04	4.30	4.83	5.61
Day 14	1.38	1.92	3.00	3.16	3.67
Volume change, %					
Day 1	1.71	1.29	1.47	2.38	2.14
Day 7	2.58	1.54	2.47	3.53	3.35
Day 14	3.53	1.83	3.41	4.62	4.68
7% initial water content					
Weight change, %					
Day 1	1.12	0.97	2.61	3.11	3.35
Day 7	1.11	1.87	3.42	3.42	3.96
Day 14	0.93	1.34	1.73	2.16	3.52
Volume change, %					
Day 1	1.32	0.97	1.19	2.14	1.39
Day 7	2.42	2.31	2.52	3.76	2.39
Day 14	3.62	2.39	3.51	4.74	4.81

[a] Percent of isolated soybean protein is based on weight of polyether polyol.

[b] Foams containing 5, 6, and 7% initial water content, respectively, based on polyether polyol.

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