Our objectives were to develop acceptable extruded snack products containing soy protein, and to evaluate the influence of soy protein type, soy level, and moisture content. Addition of soy protein increased die temperature and pressure while decreasing motor torque. Results of two consumer tests for 12 prototype products and the most acceptable three samples indicated positive responses. Acceptance correlated highly with consumer attitudes toward soy foods and prior information about health effects of soy protein. Differences between protein types suggested that formulation optimization could develop highly acceptable soy/corn extruded snacks.

Key Words: extrusion, consumer acceptance, soy protein, corn

INTRODUCTION

SOY FOODS PROVIDE NUTRITIONAL BENEFITS OTHER THAN PROTEIN fortification as indicated in several investigations. Anderson et al. (1995) presented a meta-analysis of more than 30 studies in which soy protein was substituted for animal protein and found a positive hypocholesterolemic effect when substantial quantities of soy protein were added to the diet. Other investigators (Messina and Barnes, 1991; Peterson and Barnes 1991; 1993) showed anticarcinogenic effects, possibly due to soy isoflavones that inhibited growth of human breast and prostate cancer cells. Isoflavone components of soy may be partly responsible for lower incidence of breast cancer in Asian women, who, on average, consume high amounts of soy. Such reports have increased interest in incorporating soy proteins into the diet.

Addition of soy protein to extruded corn products has been studied for making products with improved nutritional value. Texturized vegetable protein blends of corn gluten meal and soy protein have been commonly used as animal feed (Harris et al., 1988; Neumann et al., 1984). Soy-corn blends are widely used in the Food for Peace program and large amounts of corn/soy blend have been supplied as emergency relief and developmental aid to countries around the world (USAID, 1996).

Starch-based extruded snack products from blends of soy and corn have been studied, but market introduction has not been widespread. Breen et al. (1977) studied the addition of mill fractions of wheat along with isolated soy protein to extruded corn snacks and evaluated quality factors (expansion, protein content, and amino acid profiles) to enhance snack nutritional value. Blends of up to 19% soy protein with wheat millfeeds, wheat starch, and yellow corn meal were reported to yield good expansion ratios, texture, and taste. Conway and Anderson (1973) extruded yellow corn meal with defatted soy flakes (up to 40%), defatted soy flour (up to 21%), soy protein isolate (up to 22%), and soy protein concentrate (up to 28%) to evaluate suitability for seasoned, expanded snacks and as bases for gruel, soups, and beverages. They reported good visual appearance and minor soy flavors even at the highest soy levels. Park et al. (1993) studied the extrusion of soy flour, corn starch, and raw beef blends to develop an expanded snack food with increased nutritional value. Camire and King (1991) incorporated soy fiber and soy protein isolate in direct expanded, extruded snacks to enhance nutrition through protein fortification as well as fiber content. Addition of soy in general reduced the corniness, increased expansion, and darkened the extrudates. No consumer tests of soy-corn snack foods have been reported.

Problems for marketing soy-based products are perceived inferior taste quality, cost, inaccessibility in supermarkets, and improper shelf placement (Soyfoods Association of America, 1997). Thus, there are no commercial soy-based snack products in the U.S. market. Our objectives were to develop an extruded snack product containing soy protein, evaluating the influence of soy protein type, soy level, and moisture content on extrusion conditions, product physical characteristics and consumer acceptability. In addition, we investigated consumer responses to selected corn/soy extrudates in order to determine their marketability. Small scale (in-house) consumer testing was used to select products for further development and testing by larger consumer groups.

MATERIAL & METHODS

Sample preparation

The extrusion process was organized as a $3 \times 3 \times 2$ replicated factorial experiment with 3 soy protein types, 3 soy protein levels (0, 15, and 30% by weight, corn/soy blend basis), and 2 extruder moisture conditions (19 and 21% wet basis). Protein types were Soy I (Promax 70 concentrated soy protein, Central Soya; Fort Wayne, IN), Soy II (Ardex F isolated soy protein, ADM; Decatur, IL), and Soy III (Supro 670 isolated soy protein, Protein Technologies; St. Louis, MO). The base material was CCM260 degermed yellow corn meal (Lauhoff: Danville, IL), Annatto (0.0375%) and monosodium glyceride (0.25%) were added to improve product color and texture. Products were extruded with a Werner and Pfleiderer ZSK-30 twin screw extruder at 250 rpm, 13.6 kg/h, and barrel zone temperatures of 60, 80, 120, 120, and 140°C for zones 1 to 5, respectively (Table 1). Products used for sensory tests were coated with JG62-45 cheese flavoring (Williams Seasonings; Lenexa, KS) and corn oil to a final formulation of 12% cheese seasoning, 15% oil, and remainder corn/soy collet. Only one sample was collected at the 0% protein level since this sample was identical for each protein type.

Physical properties and extruder responses

A complete block design was used for measuring physical properties. The product specific volume was determined by rapeseed displacement. Color was determined by a Hunter Colorimeter (Hunter Associates; Reston, VA) on ground samples before cheese application and was recorded as L (lightness), a (redness), and b (yellowness) values. Diameters were measured with a vernier caliper on 10 samples and averaged. The extruder motor torque was measured as a percentage of maximum amperage to the drive unit. The product temperature was measured by a j-type thermocouple at the die and die pressure...
was measured with a PT411-3M pressure transducer (Dynisco; Sharon, MA). All tests were repeated 3 times for each sample production and averaged.

### In-house consumer acceptability tests

A 2×2 complete block nested within a soy protein type design (3×(2×2)) was used for the "in-house" consumer acceptability test with 12 samples containing soy ingredients. Three sessions of testing, one for each soy protein type, were conducted on three days. Four samples made with 2 soy protein levels and 2 extrusion moisture contents for each soy protein type were evaluated in a session. At each session, about 50 panelists comprising students, staff, and faculty of the University of Illinois, recruited by advertisements placed across campus, evaluated overall liking; degrees of liking for appearance, flavor, and texture; and the intensity of cheese seasoning. The panelists were judged to be current snack consumers since they volunteered to participate in the snack study. Subjects rated samples on a paper ballot, using a 9-point hedonic scale (1-extremely dislike to 9-exremely like) and 9-point intensity scale (1-not strong at all to 9-extremely strong). The volunteers received two pieces of each sample (2.5 cm) in 150 mL plastic cups labeled with randomly assigned 3-digit numbers. Water between samples.

### Central location consumer acceptability test

A completely randomized block design was used for the central location consumer test with three selected samples from the in-house test. Those samples were Soy I at 15% soy protein and 19% feed moisture, Soy II at 15% soy protein and 19% moisture, and Soy III at 15% soy protein and 21% moisture. Four hundred volunteer consumers participated at the University of Illinois College of Agricultural, Consumer and Environmental Sciences Open House over a two-day period. They evaluated the three samples in random order on a 9-point hedonic scale for overall liking. The test was conducted in a booth in the exhibition area for the open house with three panelists seated at one side of a table facing the sensory personnel. The random order of sample presentation prevented panelists from influencing each other. Each consumer was instructed in how to do the test by sensory personnel and told that the products were made of corn and soy ingredients before testing. Consumers received two pieces of each sample in 150 mL plastic cups with randomly assigned 3-digit numbers. Water was provided for rinsing between sample evaluations. Demographic information including age, gender, and personal attitude about foods containing a soy ingredient was obtained. Previous knowledge about beneficial biological effects of soy ("Have you heard about the biological effects of soy protein such as lowering cholesterol level and cancer incidence?"") was also solicited.

### Statistical analyses

Data from physical properties and consumer tests were analyzed by the GLM procedure in SAS with the LSD mean separation option to determine if there were significant differences between treatments (SAS Institute, Inc., 1991). The response distribution from the central location consumer test was analyzed by Chi-square test. Demographic and attitude data were analyzed with descriptive statistics, regression and correlation analysis. Significance of differences were defined at p<0.05.

### RESULTS & DISCUSSION

#### Physical properties and extruder responses

Adding protein had the greatest influence (p<0.05) on the Hunter b-value, where higher values indicated more yellowness (Fig. 1). Soy II had no influence on yellow color, while the Soy I product had the least yellow color. The addition of Soy I increased specific volume 25% over the no-soy product, while addition of Soy II at the 30% level decreased specific volume nearly 50% (Fig. 1). No difference was found in specific volume with addition of Soy III; however, the collet diameter decreased nearly 25%. Addition of Soy II increased diameter at the 15% level, but decreased diameter greatly (50%) at the 30% level. This contrasted with the Soy I product, which was also a soy protein isolate with similar functionality (both were promoted for applications requiring low viscosity).

Additional soy protein influenced extruder operation responses (Fig. 2). Higher die temperatures were obvious with differences found for addition of Soy I at the 30% level nearly 20°C, and an increase found with addition of Soy III at both levels of 15°C. The die temperature correlated

### Table 1—Extruder screw profile

<table>
<thead>
<tr>
<th>Zone</th>
<th>Screw element description</th>
<th>Number of screw elements</th>
<th>Length (mm) of element</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (Feed)</td>
<td>20°:FTLS undercut</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>II</td>
<td>42°:FTLS undercut</td>
<td>5</td>
<td>21</td>
</tr>
<tr>
<td>III</td>
<td>28°:FTLS</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td>IV</td>
<td>20°:FTLS</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>V</td>
<td>45°:FP</td>
<td>2</td>
<td>28</td>
</tr>
<tr>
<td>V</td>
<td>45°:RP</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>V</td>
<td>20°:FTLS</td>
<td>5</td>
<td>20</td>
</tr>
<tr>
<td>V</td>
<td>20°:FTLS</td>
<td>5</td>
<td>10</td>
</tr>
</tbody>
</table>

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\( ^a \)FTLS=forwarding twin lead screw; FP=forwarding paddle; RP=Reversing paddle.

Note: Total screw length is 115 cm with screw length/diameter of 37.
well with the specific volume ($r = 0.48, p = 0.015$). The specific volume and diameter for Soy I and Soy III products increased with an increase up to 30% soy additions along with the die temperature. However, the Soy II specific volume and diameter decreased when increasing the soy up to 30%, as with die temperature. Adding soy, all types and levels, produced decreases in motor torque (MT) and increases in die pressure (DP), with Soy II product yielding the lowest MT levels (60% lower than no soy) and Soy I at the 30% level producing the highest die pressures (250% greater). This suggests a shift in the gelatinization point towards the die, resulting in a lower degree-of-fill for gelled material and a higher viscosity at the die. Soy proteins are selected as ingredients for their water binding capacity in meats, breads, and cakes (Lusat and Rhee, 1995). A shift in gel-point toward the die was expected since the hygroscopic nature of soy protein would compete for water required for starch gelatinization. This probably also explains the higher product temperatures which were needed to promote gelatinization and fluid flow.

The influence of moisture content was determined on extrudate properties and extruder responses (Table 2). In general, a 2% difference in moisture content had little influence on the properties. The volumetric expansion was lower at the higher moisture content, possibly due to post-extrusion shrinkage (Fan et al., 1994), while the di-metral expansion was higher at the high moisture level, possibly due to an increased dough elasticity (Faller et al., 1995). Yellowness (b-value) was slightly higher at the high moisture condition possibly reflecting less browning.

### In-house consumer acceptance

Hedonic ratings were obtained for extruded samples with cheese coating (Table 3). The comparison was made only within a soy protein type due to the nested effect of the type. Descriptive statistics showed that consumer responses had a unipolar pattern, which made the mean value reliable for further analysis. In general, mean hedonic acceptance ratings for all products were slightly above the neutral point (5.0), but below “like slightly” (6.0). Hedonic responses for almost all attributes were different among samples for all 3 soy protein types. The sample containing 15% Soy I at 19% feed moisture was liked the most in terms of overall, appearance and flavor attributes. There were interactions (p < 0.05) between soy protein level and feed moisture for Soy I samples, which resulted in reduced acceptance for the sample with 15% added soy at 21% feed moisture. Soy protein level and feed moisture content for Soy I samples did not change acceptance ratings for all products were slightly above the neutral value.)

Although the amount of cheese seasoning was the same for all samples, the intensities of flavor, which were subjective responses from the consumers, were different among samples. This might be due to flavor alteration by soy protein, processing conditions, or most likely variation in coatings on the product surface. Cheese seasoning intensity was highly associated with consumer flavor ($r = 0.80, p < 0.001$) and overall liking ratings ($r = 0.72, p < 0.0001$). Overall acceptance response correlated with flavor liking ($r = 0.82$), cheese seasoning intensity ($r = 0.72$), texture liking ($r = 0.62$) and appearance liking ($r = 0.52$) in decreasing order. Thus, the flavor application seemed to be most important for consumer appeal as long as texture characteristics were within an acceptable range.

The low soy protein level/low feed moisture condition resulted in more acceptable attributes than high levels for Soy II products, whereas the low level of soy protein with high feed moisture was more liked...
for Soy III products. Thus, samples made with Soy II at 15% soy-19% feed moisture and Soy III at 15% soy-21% feed moisture were liked the most by consumers. Effects of soy protein level and feed moisture content were directly related to soy protein type in determining consumer acceptance of extruded snacks. Feed moisture had a significant effect for Soy I samples while the soy protein level did not. The protein level had a significant effect for Soy II products while moisture level did not. Neither factor affected Soy III samples. Since Soy I with 15% addition and 19% moisture, Soy II with 15% addition and 19% moisture, and Soy III with 15% addition and 21% moisture received the highest hedonic rating scores for overall liking, those products were selected for a larger scale consumer test.

Central location test

The larger scale consumer test was performed at a College Open House in Urbana. Participants took part in the test voluntarily, indicating their interest in tasting corn/soy snacks. Overall acceptance for the three selected products containing 15% soy protein at 19%, 19% and 21% feed moisture for Soy I, Soy II and Soy III, respectively, showed that 63%, 50% and 68% of consumers rated over 6 (“like slightly”) on a 9-point hedonic scale (Fig. 3). The frequency distribution among samples was different (p<0.01). Mean ratings for Soy III (6.31) and Soy I (6.13) samples were higher (p<0.0001) than for Soy II samples (5.53). Considering the unfamiliarity of the products to consumers and the end point of avoiding the highest (9) rating assignment, the results are promising for marketing of corn/soy snacks. Mean ratings were slightly higher than in the in-house consumer acceptance test, which might be due to the assimilated context effect (Lawless and Heymann, 1998) as well as variations in panelists.

The consumers (400 total) that participated in the test ranged from preschool ages to 60 (less than 10, 7%; 11-17, 50%; 18-49, 33%; over 50, 10%) with 59% female and 4l% male. Most consumers (55%) had positive attitudes about foods containing soy ingredients, such as soy milk, vegetable hamburger meat, etc., whereas only 5% expressed negative attitudes (Fig. 4). Most of the consumers > 18 yrs old showed a positive attitude and the ratio trended toward a positive attitude as age increased, while the younger testers were more neutral. Consequently, the > 50 age group showed 77% positive, 20% neutral, and 3% negative responses. A high percentage of positive and neutral attitude responses toward soy-based foods may have resulted from familiarity with soybean farming in the region. Positive trends in attitudes towards soy correlated with knowledge about beneficial health effects (p<0.001, Fig. 4). Similarly, McIsaac et al. (1993) reported that the purchase of soy-containing baked items increased after consumer education regarding health benefits of soy protein and fiber.

Consumer attitudes correlated with acceptance ratings (p<0.0001) with mean values of 6.32, 5.72, and 4.74 for positive, neutral, and negative attitudes, respectively, across all ages >10 yr old. The acceptance rating also increased (p<0.05) when consumers knew about the beneficial health effects of soy, but was not influenced by age or gender.

CONCLUSIONS

THERE IS POTENTIAL FOR EXTRUDED SOY SNACKS TO MEET CONSUMER EXPECTATIONS. Moisture content and extrusion conditions, as well as soy protein type are directly related to sensory and physical characteristics. Information available to consumers either prior to or at the point of purchase may influence product selection.

REFERENCES


Fig. 3—Overall consumer acceptance of soy/corn extruded snacks containing 15% Soy I, Soy II, or Soy III at feed moisture of 19%, 19%, and 21%, respectively.

Fig. 4—Consumer attitude about soy-based foods as related to prior knowledge about health benefits of soy protein by age group (Bars represent attitude (Att) and lines represent prior knowledge about beneficial effects).