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Use of Isolated Soy Protein in the Development of Frankfurters with Reduced Levels of Fat, Calories, and Cholesterol

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INTRODUCTION

Health organizations are encouraging people to reduce their intake of fat, calories, salt, and cholesterol since major chronic diseases such as obesity, heart disease, cancer, hypertension, and diabetes have been associated with dietary excesses (AHA, 1982; WHO, 1982; NIH, 1984). For this reason, manufactured meat products such as frankfurters are causing concern about health.

A logical step in the development of low fat frankfurters is the reformulation of traditional products with leaner meats. The use of isolated soy protein (ISP) as a replacement for part of the meat allows for a reduction in cholesterol along with the reduction in fat and calories.

Studies were conducted to develop applications information on the use of ISP in a frankfurter where the goal was to reduce its fat content from 30 to 15% while maintaining quality of the product. Topics of interest included the effects of fat, humidity of the cook schedule, ISP hydration level, ISP use level, and point of ISP addition during manufacture. In addition, the shelf life implications of a reduced fat level and a reduced brine contentration (salt expressed as a percentage of the moisture-plus-salt content) caused by the use of leaner meats were investigated. The use of potassium chloride (KCl) to increase the brine contentration was also studied.

MATERIALS AND METHODS

Formulas and Ingredients. The formula consisted of 100 parts of meat block (95 parts beef and pork, 3 parts whole egg, and 2 parts nonfat dry milk), 2.6306 parts salt and spices (2.2 salt, 0.0156 sodium nitrite, 0.120 granulated sugar, 0.120 black pepper, 0.08 allspice, 0.04 nutmeg and 0.0550 sodium ascorbate), and 30 parts water for a total of 132.6306 parts. The ratio of beef (approximately 10% fat) and pork (approximately 58% fat) varied depending upon the experiment and an all-meat (95 parts) 30% fat control (dry cook) was always prepared. Usually, an all-meat (95 parts) 15% fat control (humid cook) was also prepared. Unless otherwise stated, ISP (Purina Protein 500E from the Ralston Purina Company in St. Louis, MO.) and 3 parts water were added as a replacement for the beef and pork.

Treatments, Design, and Statistical Analysis. Six studies (A, B, C, D, E, and F), were conducted. The effects of 3 fat levels (30, 20, and 10%), 2 levels of meat replacement (0 and 22.3%) [22.3% equals 4% ISP in the final uncooked product] and 2 cook schedules (dry and humid) on the properties of frankfurters were determined in study A. All-meat controls (30 and 15% fat) were prepared for all the remaining studies and all ISP containing products were prepared at 15% fat. The effects of ISP hydration were addressed in study B and involved products containing ISP hydrated with 3, 4, 5, and 28 parts water replacing 22.3% of the meat. The effects of point of ISP addition were examined in study C and involved 4 batches where ISP was added at different places in the manufacturing process (before the beef, to the beef, with the pork, and during the last minute of chopping). The effects of various levels of meat replacement (0, 10, 20, 30, and 40%) were evaluated in study D. A comparison of 25 parts meat replacement to the replacement of 22 parts meat and 3 parts whole egg was made in study E. Shelf life (study F) was determined on 4 ISP containing batches (31.6% meat replacement) described as follows: ISP hydrated with 3 parts water, ISP hydrated with 5 parts water, 0.48% (0.64 parts) KCl and ISP hydrated with 5 parts water (approximately the same ionic strength as the 30% fat control), and 0.75% (1 part) KCl and ISP hydrated with 5 parts water. KCl was added at the expense of water. Periodically, samples were evaluated organoleptically and microbiologically.

Half of each batch from studies A, B, and C was processed with a dry cook and half was processed with a humid cook. For studies D, E, and F, the 30% fat control was given a dry cook while the 15% fat products were given the humid cook.

Study A was a complete 3 x 2 factorial design (3 fat levels by 2 meat replacement levels) with a two way split for type of cook (12 treatments). Studies B, (12 treatments) and C (12 treatments) were single factor designs with a two way split for type of cook. Studies D (6 treatments) and E (4 treatments) were single factor designs. Study F (6 treatments) was a single factor design with a split for storage time. Data were analyzed using analysis of variance and means were separated using the honestly significant difference (hsd) procedure (Steel and Torrie, 1960).

Processing. Batches (10 kg) for studies A, B, C, D, and E were prepared in a small Seydelmann chopper (K 21 Ras pp 78 113-1) while batches (20 kg) for study F were prepared in a 65 liter Kramer Grebe chopper (Type SK 01V-80L/4). Classical meat technology was used. When the salt soluble proteins were extracted from the beef, the pork was added and the batter was chopped to a final temperature of 16°C. Unless otherwise stated, ISP and 4 parts water were chopped 1 minute before the addition of beef and the remaining water was divided into 3 equal portions and added with the beef, with the pork, and near the end of the chopping sequence. Nonfat dry milk was added in the last minute of chopping and spices were added in the beginning with the salt.

The batters were vacuum stuffed (Handtmann, Type VF16/200) into 26 mm cellulose casings (Teepak, Wienie-Pak, easy peel, clear) and the linked sausages (57 gm per link) were placed on smoketrees and cooked and smoked in an Alkar Smokehouse. The dry cook schedule was: 20 minutes at a dry bulb (DB) of 60°C, no setting on the wet bulb (WB); 40 minutes at a DB of 82.2°C, no setting on the WB. The humid cook was identical to the dry cook except the second stage was 30 minutes at a DB of 82.2°C, WB of 65.6°C (45% RH). RH of the dry cook ranged 15-20%. The products were smoked during the first 20 minutes of the cycle and the internal temperature reached 72.2°C at the end of the cycle. After cooking, the frankfurters were showered, allowed to dry, covered with large plastic bags, and placed in a 1-2°C cooler overnight before being peeled and evaluated. For study F, frankfurters were vacuumed packed (3 per pack) in barrier bags (Cryovac Division, W. R. Grace & Company, Type B540, size 4 x 15, O_2 transmission 3-6 cc/M^2/24 hr at 4.44°C, 0% RH 1ATM) and stored at 4.4°C (trial 1) or 7.8°C (trial 2).

Evaluations.

- Instrumental Texture. Texture was evaluated with an Instron Universal Testing Machine (Model 1122, Instron Corp., Canton Mass.) using a modification of a procedure described by Hargett et al. (1980). Frankfurters (5 per treatment) were heated in water and evaluated between 65.6-71.1°C. A 12.7 mm cross sectional piece was cut from the center of the frankfurter and compressed (127 mm/sec) between 2 plates to 25% of its original height. The force required to fracture the sample, which was the first significant break in the force-deformation curve (chart speed, 508 mm/sec) was determined.

- Instrumental Color. Color was evaluated objectively using a Hunter Lab Color/Difference Meter D25-2 standardized with reflectance-color standard No. C2-8291 (L_L = 68.1, a_L = 21.7, b_L = 13.0). The redness (a_L) values were determined on the freshly sliced surface (cut parallel to the longest axis) of unheated samples. All treatments were evaluated in duplicate.

- pH. Treatments were evaluated in duplicate using an Orion spear tip combination electrode (8163 ROSS) and an Orior pH meter (Model No. 811).

- Chemical. Moisture, protein, fat, and ash were determined in duplicate according to AOAC (1984) procedures. Soluble chloride was determined colorimetrically using a modification of the MMCAWW (1974) procedure. The modifications consisting of extracting the sample with 0.1% HNO_3, using a dialyzer in the Tehnicon system to remove any particulate matter, and using 0.25 N HNO_3 as a diluent instead of water. Soluble chloride was used to calculate sodium chloride and the brine contentration.

- Microbiological Evaluation. Aerobic plate counts (35°C) were determined by the method of Speck (1984) while psychrotrophs were determined using the same procedure except plates were incubated at 7°C. Lactobacillus were determined by the method of Speck (1978). Microbiological evaluations were replicated a minimum of 3 times for each treatment.

- Sensory Evaluation. A 15 member panel, trained according to the methods of Civille and Szczesniak (1973) was used to evaluate frankfurters on 15 point scales for cured meat color (0 = pale, 15 = intense), hardness (0 = soft, 15 = firm), juiciness (0 = dry, 15 = juicy), chewiness (0 = no chews before swallowing, 15 = 90 chews before swallowing), and various flavor attributes (0 = weak, 15 = strong) of meatiness, spiciness, soy flavor, and aftertaste. The score sheet consisted of 15 cm nonstructured lines anchored at the end points with descriptive words. Marks characterizing a product were converted to a 15 point scale for the purpose of statistical analysis.

- Sensory Shelf Life. A 14 member experienced panel was used to evaluate frankfurters during storage. Stored samples were compared to fresh references for odor (5 = equal to reference, 4 = slight off-odor, 3 = moderate off-odor but still acceptable, 2 = strong off-odor and not acceptable, 1 = highly objectionable off-odor) and appearance (5 = equal to reference, 4 = slight excess of free liquid, 3 = moderate excess of free liquid but still acceptable, 2 = appearance of milky fluid and not acceptable, 1 = thich milky fluid with green discoloration and highly objectionable).

RESULTS AND DISCUSSION

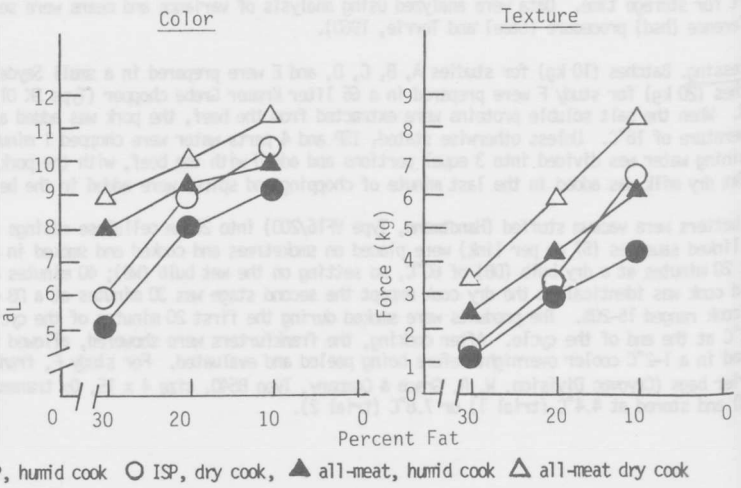
The objective color and texture tests were reliable predictors of the subjective evaluations. The Instron texture test correlated significantly ($p<0.05$) to panel scores for hardness ($r = 0.965$) while the objective color test correlated significantly to panel scores for cured meat color ($r = 0.929$).

The results of study A are illustrated in Figure 1. As the fat level was reduced, a_L values and Instron values increased significantly ($p<0.05$). With respect to both color and texture, replacement of meat with ISP significantly ($p<0.05$) reduced the impact of using leaner meats. Products cooked using a dry schedule were significantly ($p<0.05$) redder and firmer than products cooked using the humid schedule. The cook x fat and fat x ISP interactions were significant ($p<0.05$) for color while the cook x fat and cook x ISP interactions were significant for texture. A tough skin developed on products with 20% fat or less when cooked with the dry schedule.

The effects of various ISP hydration levels upon some of the frankfurter properties are summarized in Table 1 (study B). Increasing the level of hydration significantly ($p<0.05$) reduced the a_L values and Instron texture values and increased panel scores for juiciness. These results suggest that some of the juiciness which may be lost when using leaner meats can be restored by using more water.

The effects of adding ISP at various points in the manufacturing process were not large enough (data not shown) to be commercially important although statistical differences existed for some of the properties (study C). No specific trends existed where statistical differences occurred.

Figure 1. Study A. Effects of fat level, meat replacement (22.3%) with hydrated (3 parts water) ISP, and the type of cook (humid or dry) upon the Hunter-Color a_L (n = 2) values and Instron texture (n = 5) of a frankfurter.



Data summarizing the effects of various levels of meat replacement with ISP upon the properties of a 15% fat frankfurter (study D) are given in Table 2. All products with 15% fat were slightly less juicy than the 30% fat all-meat control suggesting that more hydration water was needed. Between 20 and 30% of the meat was replaced before soy flavor of the ISP product became significantly different ($p<0.05$) than the 30% fat control. Greater than 30% meat was replaced before the other sensory properties became different ($p<0.05$) than the control. The objective color and texture tests agreed with the sensory evaluation. pH increased ($p<0.05$) with the level of meat replacement. In general, properties of the 15% fat products most closely matched those of the 30% fat control when more than 20% of the meat was replaced with hyrated ISP.

The objective texture and color evaluations in study E showed that replacement of 25 parts of the meat block as meat and whole egg resulted in a firmer and paler product than replacement of 25 parts of the meat block as meat (data not shown). These differences were not large enough to be detected organoleptically and the panel judged both products to be equal ($p>0.05$) in all parameters. Obviously, replacement of whole egg is a prime consideration in any product where the overall objective is a reduction in cholesterol.

Table 1. Study B. Effects of ISP hydration level upon the Hunter-Color a_L value, Instron texture, and juiciness of a 15% fat frankfurter (22.3% of the meat replaced with hydrated ISP)*

	All-meat controls		Water:ISP Ratio			
Property	30% fat	15% fat	3	4	5	28
a_L Value (n = 4)	8.38 D	11.08 A	9.55 B	8.98 C	8.95 C	8.37 CD
Force (kg) (n = 10)	3.03 D	5.92 A	4.41 B	3.90 BC	3.91 BC	3.30 CD
Juiciness (n = 15)	8.01 B	5.31 C	6.18 BC	7.14 BC	8.18 B	10.66 A

*Juiciness values represent the dry cook while other means are averages of the dry and humid cooks. Within a row, values sharing a common capital letter are not significantly different ($p>0.05$).

Table 2. Study D. Effects of level of meat replacement with hydrated ISP upon the sensory evaluation, pH, Hunter-Color a_L value, and Instron texture of a 15% fat frankfurter*

	All-meat control 30%	Percent meat replaced with hydrated ISP				
Property	fat	0	10	20	30	40
Sensory (n = 13)						
Cured Meat Color	5.12 CD	9.15 A	7.41 B	6.42 BC	3.69 DE	2.07 E
Hardness	3.78 D	9.23 A	7.18 B	7.09 BC	5.28 CD	4.49 D
Juiciness	8.91 A	7.11 B	6.90 B	6.21 BC	6.39 BC	4.80 C
Chewiness	4.38 C	6.00 A	5.31 AB	4.68 BC	4.65 BC	3.58 D
Meatiness	6.59 BCD	8.44 A	7.51 ABC	6.18 CD	5.08 D	3.29 E
Spiciness	4.52 A	5.16 A	5.69 A	4.25 A	5.73 A	5.18 A
Soy Flavor	2.48 C	2.00 C	2.79 C	3.55 C	7.03 B	8.97 A
Aftertaste	4.77 B	4.99 B	5.05 B	5.89 B	6.27 B	10.06 A
pH (n = 2)	6.365 D	6.315 E	6.365 D	6.410 C	6.440 B	6.500 A
a_L value (n = 2)	8.50 D	10.00 A	10.05 A	9.30 AB	7.45 C	6.40 E
Force (kg) (n = 5)	2.94 BC	4.16 A	3.60 AB	3.46 AB	3.15 B	2.42 C

* Within a row, values sharing a common letter are not significantly different ($p>0.05$).

Data concerning the chemical and sensory properties of frankfurters prepared for the shelf life evaluation (study F) are summarized in Table 3. The fat contents of all treatments closely matched targeted values. Reducing the fat content from 30 to 15% in the controls significantly ($p<0.05$) increased moisture and protein and reduced the brine concentration by approximately 14%. Total chloride was converted to NaCl for the brine calculation. The composition of the low fat product containing ISP hydrated with 3 parts water was identical in every parameter to the composition of the 15% fat control. Hydrating with 5 parts water significantly ($p<0.05$) increased moisture and reduced protein. This did not affect the brine concentration. Adding KCl significantly ($p<0.05$) increased the brine concentration although the difference between the 2 levels was not quite large enough to be statistically significant ($p>0.05$). The brine concentration of both KCl products were equivalent ($p>0.05$) to that of the 30% fat all-meat control.

Table 3. Study F. Chemical and sensory properties of various frankfurters prepared for storage tests*

	All-meat controls		Hydrated ISP replacing 31.6% meat			
Property	30% fat	15% fat	1:3 hyd.	1:5 hyd.	1:5 hyd. 0.48% KCl	1:5 hyd. 0.75% KCl
Chemical (n = 4)						
Moisture (%)	56.6 D	65.2 C	65.8 BC	67.7 A	67.7 A	67.3 AB
Protein (%)	12.1 C	15.4 A	15.5 A	14.0 B	13.8 B	13.8 B
Fat (%)	29.3 A	15.7 B	14.9 B	15.4 B	14.3 B	14.5 B
Ash (%)	2.35 B	2.49 B	2.55 B	2.45 B	3.03 A	3.15 A
Chloride (%)	1.01 B	1.00 B	0.96 B	1.00 B	1.23 A	1.29 A
Brine (%)	2.85 A	2.45 B	2.36 B	2.37 B	2.91 A	3.05 A
Sensory (n = 18)						
Cured Meat Color	8.06 B	11.31 A	6.99 B	6.78 B	7.21 B	7.16 B
Hardness	7.24 B	11.64 A	7.07 B	7.66 B	6.94 B	6.83 B
Juiciness	10.54 A	8.64 A	7.01 A	8.66 A	8.60 A	8.21 A
Chewiness	5.65 B	7.41 A	6.03 B	6.12 B	6.11 B	5.85 B
Meatiness	8.50 AB	9.88 A	7.44 B	7.61 B	7.96 B	7.56 B
Spiciness	7.52 A	8.69 A	7.38 A	6.91 A	6.71 A	6.70 A
Soy Flavor	2.40 C	2.46 C	6.96 A	5.06 AB	4.63 BC	5.25 AB
Aftertaste	4.50 A	5.06 A	5.19 A	5.49 A	5.00 A	5.27 A

* Means are the average of trials 1 and 2. Within a row, values sharing a common letter are not significantly different ($p>0.05$).

Lowering the fat contents from 30 to 15% in the controls significantly ($p<0.05$) increased cured meat color, hardness, and chewiness. The difference in juiciness was not quite large enough to be statistically significant ($p>0.05$). The use of ISP in all products balanced the effects of using leaner meats with respect to cured meat color, hardness, and chewiness. Except for soy flavor, the properties of the ISP products were equivalent ($p>0.05$) to those of the 30% fat control. The properties of the ISP product with 5 parts water and 0.48% KCl matched those of the 30% fat control in every category. Slight differences in soy flavor, where they occurred, were expected at this high level of meat replacement. Although the differences were not statistically

significant ($p>0.05$), hydrating with 5 parts water increased juiciness in constrast to hydrating with 3 parts water. The effects of KCl upon the flavor attributes were not statistically significant ($p>0.05$).

Except for the 30% fat control, odor and appearance of the frankfurters stored at 4.4°C (trial 1) were stable over 14 weeks (data not shown). At 14 weeks, the odor and appearance scores of the 30% fat control were 3.38 and 2.85, respectively, which were significantly ($p<0.05$) lower than the scores of other treatments. Physical and chemical changes rather than microbial spoilage were the most likely causes of deterioration since bacteria (data not shown) developed slowly on all products and never exceeded log 3.53.

Table 4. Study F. (trial 2). Effects of storage at 7.8°C upon the appearance, odor, and bacterial counts (log CFU/g) of various frankfurters

	All-meat controls		Hydrated ISP replacing 31.6% meat			
	30% fat	15% fat	1:3 hyd.	1:5 hyd.	1:5 hyd. 0.48% KCl	1:5 hyd. 0.75% KCl
Property						
Appearance (n = 14)						
0 Weeks	4.67 Aa	4.92 Aa	4.67 Aa	4.25 Aa	4.67 Aa	4.67 Aa
4 Weeks	3.14 Ab	3.86 Ab	3.71 Aa	3.43 Aa	3.29 Ab	3.36 Ab
Odor (n = 14)						
0 Weeks	4.33 Aa	4.50 Aa	4.42 Aa	4.33 Aa	4.67 Aa	4.50 Aa
4 Weeks	3.64 Aa	4.07 Aa	3.64 Aa	4.00 Aa	3.93 Aa	3.79 Aa
Aerobic Counts						
0 Weeks (n = 3)	2.93 Ab	3.16 Ab	2.96 Ab	3.01 Aa	3.05 Aa	3.06 Aa
2 Weeks (n = 3)	4.16 ABab	5.89 Aa	4.08 ABb	3.32 ABa	2.56 Ba	2.73 Ba
3 Weeks (n = 4)	5.22 Aab	6.26 Aa	5.03 ABab	2.43 Ca	2.92 BCa	1.92 Ca
4 Weeks (n = 5)	5.74 Aa	6.23 Aa	6.87 Aa	3.61 Ba	3.06 Ba	2.94 Ba
Psychrotrophic Counts						
0 Weeks (n = 3)	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa	0 Aa
2 Weeks (n = 3)	4.57 ABab	5.93 Ab	4.42 ABab	1.91 ABa	0 Ba	0 Ba
3 Weeks (n = 4)	5.63 Ab	6.12 Ab	5.33 Ab	1.77 Aa	3.67 Aa	3.78 Aa
4 Weeks (n = 5)	6.43 Ab	6.30 Ab	6.95 Ab	1.81 Ba	0.89 Ba	0.55 Ba

* Within a test, means sharing a common uppercase letter in a row are not significantly different ($p>0.05$); means sharing a common lower case letter in a column are not significantly different ($p>0.05$).

To promote microbial spoilage, trial 2 (Table 4) was conducted at a mild abuse temperature (7.8°C). For both odor and appearance, the effects due to time were significant ($p<0.05$) while effects due to treatment and the time x treatments interaction were not significant ($p>0.05$). Odor and appearance are regarded as the most important criteria of shelf life.

For both aerobic and psychrotrophic counts, the effects of time, treatments, and the treatment x time interaction were significant ($p<0.05$). After processing, microbial counts for all treatments were equivalent ($p>0.05$) which suggested that either cook schedule (humid or dry) provided the same lethality. Aerobic and psychrotrophic counts developed faster in the controls and the product containing ISP hydrated with 3 parts water than in the other treatments. The differences between the controls and the product hydrated with 3 parts ISP were not significant ($p>0.05$) at any period. Lactobacillus (data not shown) developed slowly and showed no treatment effect ($p>0.05$).

It was not conclusively shown that the reduction in brine contentration promoted microbial development since bacteria in the controls developed at the same rate and bacteria in the ISP products with 5 parts water and KCl developed at the same rate as bacteria in the product with ISP and 5 parts water. Bacteria developed faster in the ISP product with 3 parts water than in the ISP product with 5 parts water. However, none of the differences in microbial development were reflected in differences in odor/flavor characteristics during storage.

SUMMARY AND CONCLUSION

Using leaner meats to reduce the fat content of all-meat frankfurters caused the products to become darker in color and tougher in texture. Replacement of 20% or more of the meat with hydrated ISP in the 15% fat products reversed the negative effects of using leaner meats. Using a high cook humidity (45% RH) reduced firmness and cured meat color and prevented a tough skin formation in low fat frankfurters. Increasing the level of ISP hydration helped replace juiciness which was lost when the fat was reduced. Point of ISP addition during processing was not critical. Replacement of 25 parts of the meat block as meat or as meat and whole egg resulted in final products with similar organoleptic properties. The shelf life of 15% fat products was equal to or greater than the shelf life of the 30% fat all-meat control. The effects of KCl upon flavor and shelf life were not significant. ISP was extremely useful in formulating 15% fat frankfurters with eating qualities that matched those of the 30% fat all-meat control.

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