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Chemical, Physical and Sensory Properties of Expanded Extrudates from Pork Meat-Defatted Soy Flour-Corn Starch Blends, With or Without Ingredients Derived from Onion, Carrot and Oat

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Abstract

Blends of pork meat (20%), defatted soy flour (25%), and corn starch (48.61~53.71%) were prepared with or without additional non-meat ingredients, i.e., onion powder (1%), alone or in combination with carrot powder (1.5%) or extract (1.5%), or defatted oat flour (5%). All blends were formulated for 22.78% moisture, with water added where necessary. They were extruded using a laboratory single-screw extruder at 160°C process temperature and 170 rpm screw speed. The additional ingredients generally decreased product expansion and increased bulk density and shear force. When the product with no additional ingredient and the product with onion powder were evaluated by trained sensory panelists, "grain complex" was the most intense flavor note for both. With 1% onion powder in feed, a distinct "onion" flavor note was detectable in extrudates. All the products may be considered "healthful" based on nutrient profiles.

Key words: extrusion, pork, soy flour, corn starch, onion, carrot, oat flour, product properties

INTRODUCTION

Snack food consumption is increasing (1). Among snack foods, those based on cereals and grains, which generally are not high in nutrient density, are the most widely consumed today. To increase the nutritional contribution of snack consumption, attempts have been made to develop high-protein/low-fat, snack-like products through extrusion cooking/puffing of blends of meat (such as beef, pork, lamb, and mutton) and non-meat ingredients (2-7), with defatted soy flour (DSF) often used as a high-protein non-meat ingredient (2,5,7). When DSF was used at ~50% level in the feed (raw material mixture to be extruded) containing 22% corn starch and 20~29% raw/non-dehydrated meat (beef, lamb, or pork), some trained panelists detected beany or hay-like flavors in extrudates (2,5). Thus, the DSF content in feed was reduced to 25% in our recent study (7). Since changes in feed composition profoundly influence the extrusion performance and extrudate quality, we had to establish a new set of extrusion condition, with the same extruder, to produce minimally hard, expanded extrudates, focusing on process development/optimization for blends of 20% pork meat, 25% defatted soy flour, and cornstarch (7). The objectives of the present study were to characterize the extrudates produced from a 20% pork meat-25% defatted soy flour-cornstarch blend under the final extrusion condition of the companion study (7) and to determine the effects of pre-extrusion incorporation of onion, carrot and oat products on various quality traits of extrudates.

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MATERIALS AND METHODS

Materials and extrusion

The ground pork meat, defatted soy flour, and corn starch used previously in the process development/optimization study (7) were also used in this study. Other ingredients were defatted oat flour (AVEOATSTM Lo-Fat; 8.61% moisture) from Con Agra® Specialty Grain Products, Omaha, NE; onion powder (Fresh Flavor) and carrot powder from Basic Vegetable Products, Suisun, CA; and freeze-dried carrot extract (Veg-Dry Carrot Color Stable) from Florida Food Products, Inc., Eustis, FL.

A single-screw laboratory extruder (Type 1503) from C. W. Brabender Instruments, Inc. (South Hackensak, New Jersey) was used. Diameter of the extruder barrel was 1.91 cm and its length-to-diameter ratio was 15 : 1. A screw with a compression ratio of 4 : 1 and a die with a nozzle diameter of 6.35 mm were used. Feeder speed, temperature of the first zone (feeding section) of the barrel, and temperature of the second zone (mixing section) were set constant at 50%, 20°C and 150°C respectively. The temperature of the third zone of the barrel (denoted as process temperature), screw speed and feed moisture were 160°C, 170 rpm and 22.78%, respectively, as in the final extrusion of the companion study. Details for feed preparation and extrudate handling have been described previously (7). Table 1 shows feed formulations and product designations for the five products produced in this study. Note that the product made with basic ingredients only (with no additional non-meat ingredient) was designated as

B (as in basic). Feed preparation for each product was replicated three times to conduct triplicate extrusion runs per product. Between runs, the extruder was shut down and cleaned before starting up anew for the next run, either on the same day or on later days.

Determination of physical, chemical and nutritional properties

Expansion ratio (ER), bulk density (BD), shear force (SF), and Hunter color values were determined as described previously (7). Moisture (by oven-drying), protein and ash contents were determined according to AOAC (8) procedures, after grinding extrudates in a coffee grinder. Total fat content was determined as described by Park et al. (2), with lipids extracted from ground/hydrated extrudates using 2 : 1 chloroform-methanol as the extraction medium (9). Total carbohydrate percentage was estimated by difference, i.e., 100% minus percentages of moisture, protein, ash, and total fat. To determine fatty acid composition, aliquots of total fat extracts were transmethylated (10) and fatty acid methylesters were analyzed by gas chromatography (11). Amino acid composition was determined on acid hydrolyzates of extrudates by fluorometric high-performance liquid chromatography (12).

Nutritional values for one serving (28 g) of extrudates were estimated. Caloric content was calculated based on 9 kcal/g fat and 4 kcal/g carbohydrate or protein. Saturated fat content was estimated from total saturated fatty acid data. The % Daily Value for each nutrient was calculated based on a 2,000 kcal diet.

Sensory evaluation

Sensory evaluations were conducted using an 11-member trained panel. Only B and OP were evaluated to avoid potential sensory fatigue of panelists. (Cursory/preliminary evaluations among our laboratory personnel revealed that, in terms of flavor attributes, OAT was not notably different than B, while OCP and OCE were not distinctly different from OP.) Panelists were graduate students, faculty, staff, and visiting scientists at Texas A&M University--all in the Animal Science Department, except two visiting scientists from the Food Protein Research and Development Center. They were trained to evaluate the extrudates for aromatics, tastes, aftertastes and texture attributes on a 0 ~ 15 scale (13). The specific attributes to be included in the ballot were selected during training sessions. Six training sessions (~1 hr/session/day) were held. Panelists were trained using products with known or assigned scores (products referred to as references ; Table 2) for each attribute included. Extrudates similar to test samples, in texture and flavor, were also included during the latter part of the training sessions.

Two test sessions (one per day) were held, with each product served three times in each session. This serving design resulted in a total of six evaluations per product (3 evaluations/session $\times$ 2 sessions). In each test session, a warm-up extrudate sample was provided to ensure the consistency of panelists use of the evaluation scale. Samples were evaluated under red light to avoid bias due to color. Panelists were instructed to expectorate each sample after evaluation. Apple juice, unsalted crackers and water (purified by reverse osmosis) were provided for cleansing/rinsing the palate between samples.

Statistical analysis

The Statistical Analysis System (SAS) software, version 6.11 (14) was used to perform data analysis. All data were analyzed by analysis of variance using the GLM Procedure. Data for physical properties were analyzed as a randomized block design, with processing (extrusion) replication used as the block. For sensory data, panelist and session were also included in the model. Means were separated using the Student-Newman-Keuls test. Pearson correlation coefficients were also computed where necessary. Significance was established at $p \leq 0.05$ unless otherwise indicated.

Table 1. Feed formulations

Product[2)]	Basic ingredient (%)[1)]				Additional non-meat ingredient
	Pork lean	Corn starch	DSF[3)]	Added water	
B	20.00	53.71	25.13	1.16	None
OP	20.00	52.59	25.13	1.28	1% onion powder
OCP	20.00	50.92	25.13	1.45	1% onion powder + 1.5% carrot powder
OCE	20.00	50.92	25.13	1.45	1% onion powder + 1.5% carrot extract
OAT	20.00	48.61	25.13	1.26	5% defatted oat flour

[1)]Moisture values: 72.83% for pork lean; 11.47% for corn starch; 5.84% for DSF.
[2)]B = product made with only basic ingredients; OP = product made with basic ingredients plus onion powder; OCP = product made with basic ingredients plus onion powder and carrot powder; OCE = product made with basic ingredients plus onion powder and carrot extract; OAT = product made with basic ingredients plus defatted oat flour.
[3)]Defatted soy flour.

RESULTS AND DISCUSSION

Composition and nutrient profiles for product B

Only B was evaluated for proximate composition (Table 3), nutritional values (Table 4), and fatty acid and amino acid profiles (Tables 5 and 6), because other products were not markedly different from B in terms of the levels of the major raw materials used (pork meat, DSF and corn starch). Note that B corresponds to the final product of our previous study (7), which focused on process development/optimization. B was low in fat and moisture and high in protein (Table 3). It was a more nutritious product when compared to either fried or baked, cereal-based snacks (extruded products) and other savory snacks presented in the USDA Nutrient Database for Standard Reference, Release 12 (15). According to the database, protein and fat contents of commercially available corn-based extruded chips, cones, or puffs/twists were 5.8 ~ 7.6% and 26.9 ~ 34.4%, respectively. The fat content of B (3%) was comparable to that of plain, hard

Table 2. Reference products used in sensory evaluation training and their assigned scores on a 0~15 scale[1)]

Texture references
- Roughness*
  - Jello gelatin dessert (0.0)
  - Orange peel (5.0)
  - Pringles potato chips (8.0)
  - Hard granola bar (12.0)
- Hardness*
  - Cream cheese (1.0)
  - Egg white (hard cooked) (2.5)
  - Yellow American process cheese/Land O'Lakes (4.5)
  - Olives (6.0)
  - Peanuts (9.5)
  - Almonds (11.0)
  - Lifesavers (14.5)
- Denseness*
  - Cool Whip (0.5)
  - Nougat (4.0)
  - Whoppers (6.0)
  - Frankfurter (9.0)
- Tooth packing*
  - Mini clams (0.0)
  - Fresh mushrooms (3.0)
  - Graham cracker (7.5)
  - Yellow American process cheese/Land O'Lakes (9.0)
- Residual particles
  - Cheetos Puffs/Frito-Lay (2.0)
  - Pork rinds (4.5)
  - Cheetos Crunchy/Frito-Lay (6.0)
  - Hard pretzel (9.0)

Aromatics references
- Grain complex*
  - Cream of Wheat (4.5)
  - Ritz cracker (6.0)
  - Triscuit (8.0)
- Rice
  - Corn Chex (2.0)
  - Rice Chex (3.0)
- Dried grassy
  - Extrudate made from lamb and corn starch (2.0)
  - Dried grass (15.0)
- Onion
  - Funyun onion snack (6.5)
  - Onion powder (15.0)

Sweet taste* reference
- 2% Sucrose solution (2.0)
- 5% Sucrose solution (5.0)

1)The reference products of an attribute with * mark are Spectrum™ intensity scale (0 to 15) references (13).

pretzels (3.5% fat) listed in the database. However, the protein content of the pretzels was only 9.1% (15). In protein content, B was more comparable to beef jerky (33.2% protein) (15). Table 4 shows caloric content and total fat, saturated fat and protein values for one serving (28 g) of B and the respective % Daily Values, all of which will be needed for nutritional labeling of the product.

Oleic acid (18 : 1) was the most predominant fatty acid in B, followed by palmitic acid (16 : 0) (Table 5), as in raw pork meat (separable lean) (15). Linoleic acid (18 : 2) was the third major fatty acid. In general, the fatty acid profile of B followed that of the pork meat, which was the major source of fat in all five products. The lysine content of B, 1.4 g/100 g sample (Table 6), was higher than that of snacks based on cereal grains or potatoes (<0.5 g/100 g) (21). Amounts of methionine and other essential amino acids were also greater in B than in the latter (<0.2 g/100 g). The amino acid pattern of B followed that of DSF (15), the ingredient which contributed the most protein to the product.

Table 3. Proximate composition of the product made with pork, defatted soy flour and corn starch with no additional non-meat ingredient incorporated in feed formulation (product B)

	Mean[1)] (standard deviation)
Moisture (%)	4.00 (0.29)
Fat (%)	3.03 (0.12)
Protein (%)	34.24 (2.32)
Ash (%)	2.45 (0.03)

1)Mean values of extrudates from three processing runs.

Table 4. Estimated nutritional values for the product made with pork, defatted soy flour and corn starch with no additional non-meat ingredient incorporated in feed formulation (product B)

	Values per 28-g serving[1)]	% Daily value[2)]
Calories (kcal)	109	
Calories from fat (kcal)	8	
Total fat (g)	0.85	1.3
Saturated fat (g)	0.31	1.6
Protein (g)	9.59	16.0
Total carbohydrate (g)	15.77	5.3

1)About 70 pieces (6 cm/piece).
2)Percentages based on a 2,000 kcal diet.

Table 5. Fatty acid composition of B, the product made with pork, defatted soy flour and corn starch with no additional non-meat ingredient incorporated in feed formulation

Fatty acid	Percentage of fatty acid		
	Product B[1)]	Pork lean[2)]	Defatted soy flour[3)]
10 : 0	0.11	0.14	0.00
12 : 0	0.07	0.14	0.00
14 : 0	0.97	1.40	0.34
16 : 0	25.23	24.62	11.38
16 : 1	2.91	3.50	0.34
18 : 0	10.33	12.03	3.87
18 : 1	36.02	45.87	23.44
18 : 2	23.04	9.65	53.47
18 : 3	0.11	0.42	7.17
20 : 1	0.53	0.84	0.00
20 : 4	0.68	1.40	0.00
Total saturated	36.71	38.32	15.59
Total monounsat.	39.46	50.21	23.78
Total polyunsat.	23.83	11.47	60.64

1)Percentage of individual fatty acid based on the sum of all identified fatty acids. An extrudate composite of three processing replicates was used for analysis.
2)Calculated from the per-100 g data from the USDA (15) on raw (fresh), separable lean from shoulder, blade, or boston.
3)Calculated from the per-100 g data (15).

Physical properties

B and OP were the most expanded products (Table 7). Al-

Table 6. Amino acid composition of B, the product made with pork, defatted soy flour and corn starch with no additional non-meat ingredient incorporated in feed formulation

Amino acid[1)]	g /100 g extrudate[2)]
Aspartic acid	2.5
Glutamic acid	4.1
Serine	1.2
Histidine*	0.5
Glycine	1.0
Threonine*	0.9
Arginine	1.6
Alanine	1.1
Tyrosine	0.9
Methionine*	0.5
Valine*	1.2
Phenylalanine*	1.1
Isoleucine*	1.0
Leucine*	1.8
Lysine*	1.4

[1)]An amino acid followed by * mark is an essential amino acid.
[2)]An extrudate composite of three processing replicates was used for analysis.

Table 7. Physical and rheological properties of products made with pork, defatted soy flour and corn starch with or without additional non-meat ingredients[1)]

Product[2)]	Expansion ratio	Bulk density (g/L)	Shear force (kg/g)	Hunter color		
				L value	*a* value	*b* value
B	0.860[a]	300[d]	18.75[c]	68.74[b]	2.06[b]	17.07[d]
OP	0.862[a]	389[b]	20.10[c]	71.07[a]	0.91[c]	17.00[d]
OCP	0.817[c]	354[c]	24.19[b]	68.80[b]	2.77[a]	20.24[b]
OCE	0.772[d]	442[a]	32.72[a]	68.55[b]	3.28[a]	23.52[a]
OAT	0.837[b]	281[d]	26.87[b]	65.68[c]	3.50[a]	17.93[c]

[1)]Means within the same column which are not followed by a common superscript letter are significantly different ($p<0.05$). Analyses were done on extrudates from three processing runs per product.
[2)]See Table 1 for product descriptions and feed formulations.

though these extrudates were smaller in diameter than the die used--their ER values being less than 1--they still showed the characteristic of an adequately puffed product; air cells in the extrudates were well-developed upon visual examination of their cross-sections. Nevertheless, B was a less expanded product when compared to the product produced by Park et al. (2) from a blend of beef lean (20%), DSF (50%) and high-amylose corn starch (22%). The same extruder was used in the two studies, but Park et al. (2) used a die with smaller diameter (3.175 mm vs. 6.35 mm in this study) and their extrusion was done at 29.1% feed moisture, 162°C process temperature, and 170 rpm screw speed. The ER difference (1.29 vs. 0.86 in this study) between the two studies could be largely due to the difference in die nozzle diameter. In the extrusion of corn grits with a single-screw extruder (16), extrudate ER decreased with an increase in die nozzle diameter--a 42% decrease in ER with a 112% increase in the diameter (from 2 mm to 4.23 mm). Note that the diameter of the die used in the present study was twice as large as the diameter of the die used by Park et al. (2).

Any additional ingredient that decreased starch, or increased sugars or plant cell-wall materials, in feed seemed to decrease the extrudate expansion (Table 7). Among the products with additional non-meat ingredients, OAT was the most expanded, because defatted oat flour (5%) substituted for corn starch should still have provided some starch. In extrusion of blends of beef meat, corn starch and DSF, starch was responsible for well-developed expanded structure of extrudates (2). Although the total amount of additional non-meat ingredients in feed was the same (i.e. 2.5%) for OCP and OCE, expansion was less for OCE. The high sugar content of the carrot extract (49.7% sugars, according to the supplier) used for OCE may have decreased extrudate expansion. Sugars absorb more water when compared to starch, making less steam available to aid in expansion of air cells during the flashing/puffing phase of extrusion (17). On the other hand, the decreased expansion of OP and OCP, compared to B, may be related to the insoluble, plant cell-wall materials from the onion and carrot powders, as the cell-wall materials may resist deformation through the die (18).

BD values (Table 7) indicated that B and OAT were the least dense products and OCE was the most dense. B and OP required the least force to break (SF), whereas OCE (exhibiting the lowest ER and highest BD values) required the most force. As for color, OAT was the darkest (as shown by the lowest Hunter color *L* value), probably due to the color contributed by defatted oat flour, which already was brownish before the extrusion process. OAT, OCE and OCP exhibited the highest red color (Hunter color *a*) values, while OCE had the most yellow tones (Hunter color *b* value). The carotenoid pigments in carrot powder and extract probably contributed to the red and yellow hues. The higher *a* value of OAT, compared to B and OP, could be due to the brown tones of the oat flour.

Sensory evaluation

Sensory scores for B and OP are shown in Table 8 (cf. Table 2 for assigned scores of the reference products). Among the aromatics evaluated, "grain complex," an aromatic of grains/cereals, was most intense, followed by "rice," although no rice-derived ingredient was used for either product. "Dried grassy" scores were low for both products (< 1.5 on a 0~15 scale). The "onion" aromatic and aftertaste were detected only in OP, indicating that 1% of onion powder in feed was sufficient to impart an oniony flavor note in the extrudate, in spite of the flashing/puffing process which the cooked mass had undergone.

OP, when compared to B, was harder and rougher, and left more residual particles in the mouth. It was less hard than cocktail peanuts, comparable to Pringles potato chips (Procter & Gamble, Inc., Cincinnati, OH) in roughness, and close to a corn-based extruded snack (Cheetos Crunchy; Frito-Lay, Plano, TX) in residual particles left in the mouth (Table 8, in conjunction with Table 2). Both B and OP were rated slight-

Table 8. Sensory scores[1)] for products made with pork, defatted soy flour and corn starch, without or with 1% onion powder added in feed formulation

Sensory attribute	Product[2)]	
	Without onion powder (B)	With onion powder (OP)
Aromatic		
Grain complex	7.0[a]	6.8[b]
Rice	2.8[a]	2.6[a]
Dried grassy	1.4[a]	1.5[a]
Onion	0.0[b]	2.0[a]
Aftertaste		
Onion	0.0[b]	1.3[a]
Taste		
Sweet	0.4[b]	0.6[a]
Texture		
Roughness	7.3[b]	8.0[a]
Hardness	7.4[b]	8.0[a]
Denseness	5.3[b]	5.5[a]
Tooth packing	6.1[a]	6.2[a]
Residual particles	5.3[a]	5.5[a]

[1)]Scores based on a 0~15 scale. Means within a row which are not followed by a common superscript letter are significantly different ($p<0.05$).
[2)]One strand evaluated at one time.

ly less dense than malted milk balls (Whoppers; Hershey Chocolate, Hershey, PA). Although sweet taste scores were low for both products, OP was given slightly higher ($p<0.05$) scores.

CONCLUSIONS

The products produced in this study were superior in nutritional values to commercially available, popular snacks today. The addition of ingredients derived from onion, carrot or oat to a feed mix consisting of pork meat (20%), DSF (25%) and corn starch, with feed moisture adjusted to 22.78%, decreased expansion and increased density and shear force of extrudates. Trained-panel sensory evaluations of B (the basic product made with only pork, DSF and corn starch) and OP (the product containing onion powder) indicated no notable or distinct off-flavors. With 1% onion powder used in feed, onion flavor was detectable in extrudates. It remains to be seen if a lower level of onion powder in feed still would give an oniony flavor note in extrudates, and if such a level would be sufficiently lower to cause no adverse effects on texture. To reduce the costs of the products, less expensive starch-rich ingredients (such as corn meal and flour), rather than an isolated starch product (e.g., corn starch), could be used. However, such replacement will require substantial modifications of extrusion conditions.

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