MANUFACTURE AND CHARACTERISTICS OF SNACK-TYPE PRODUCTS CONTAINING MEAT AND STARCH

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ABSTRACT

Extrusion conditions were optimized for blends of ground lamb and starch using a single-screw extruder for the purpose of producing expanded snack-type products. A central composite rotatable response surface methodology(RSM) design was used with variation in feed moisture, process temperature, and screw speed. The three variables significantly affected one or more of the measured physical properties of extrudates. The optimum conditions for minimum shear force values were 26.5% feed moisture, 148℃ process temperature, and 134 rpm screw speed. Lean ground beef, chicken, goat, lamb or mutton was blended with corn starch, and extruded at the optimum condition established from RSM experiments. Physical/rheological properties were generally similar, water activity was low (<0.12) and total aerobic plate counts were <10 for all products. Extrudates containing chicken had the highest ratio of polyunsaturated fatty acids to saturated fatty acids, whereas those containing beef had the highest ratio of monounsaturated fatty acids to saturated fatty acids. Sensory data indicated that texture was acceptable and flavor characteristics were not different among the products.

INTRODUCTION

Consumption of snack foods has increased due to their convenience and satisfaction of short term hunger with small portions[39]. Extrusion technology is widely used in the manufacture, under various proccessing conditions, of such diverse products as breakfast crereals, pastas, croutons, bread crumbs, pet foods, and snack foods from numerous ingredients[14]. It has been shown that raw material composition affects the reactions that take place during thermoplastic extrusion as well as the texture of the final product[13]. A number of products have been successfully extruded from meat in combination with nonmeat ingredients[18,22,23,27,28]. Various types of meat, such as dried offal meat, mechanically separated or hand deboned meat, dried or semi-dried ground meat, defatted chopped meat, and non-dehydrated meat, have been used as meat sources. Soy proteins products and various cereal starches or flours also have been used as nonmeat ingredients.

The consumption of lamb and mutton is limited in the U.S. and many other countries. The consumption of sheep meat has been attributed to the objectionable species-related cooking odor and flavor of the cooked meat[33,37,41]. Mutton has low commercial use since it is less acceptable than lamb and other red meats. It has an objectionable flavor, toughness and waxy fat[41]. According to Schönfeldt et al.[35], sheep meat was more tender, contained less fibrous tissue residue, and had more intense species flavor than goat meat. They also confirmed that the meat of older animals, regardless of whether sheep or goat, is less tender and has more typical species flavor than that of younger animals. Goat meat tended to be less desirable in flavor than pork, less tender than pork, beef or lamb, and less palatable overall than pork, beef or lamb when samples of comparable maturity and fatness were compared[36]. Naude. and Hofmeyr[25] reported that a trained sensory panel found goat meat less tender than either lamb or mutton, although the collagen solubility of goat meat was not markedly lower than that of lamb. Spent hens have minimal economic value in the U.S. although they are good protein sources; spent hen meat is very tough in comparison to meat from broilers and roasters[5] because of its higher collagen content. The collagen becomes less soluble with age because of cross linking of hydroxylysine aldehyde to form a keto-amine cross-linkage. Extrusion technology could be useful for the development of low cost, nutritious, and shelf-stable food products containing low values of meat. When mutton, goat meat, and spent hen meat are used in the manufacture of value-added products with substantial amounts of nonmeat ingredients, the undesirable characteristics of these meats discussed previously may be overcome through interactions among ingredients as promoted by processing technology, such as extrusion cooking. Therefore, the objectives of this study were to optimize extrusion processing variables such as feed moisture, process temperature, and screw speed for blends containing lamb and starch to produce acceptable expanded products, and to test different meat sources based on this starch matrix and to evaluate the rheological and sensory properties of finished products. Beef was included for comparison.

MATERIALS AND METHODS

Preparation of sample

Corn starch (Cereal Crisp; pregelatinized, 38% amylose) was obtained from National Starch and Chemical Corp. (Bridge Water, NJ). Ground lamb lean and corn starch were formulated to give target moisture levels of 22.9, 25.8, 28.7, 31.6, or 34.5% in the final mixture (Table 1). Ground lean meat was blended with starch in appropriate amounts using the User Friendly Feed Formulation[29] to meet the target moisture level of feed (raw material blend for extrusion). Ground lean meat was first chopped in a food processor (Cuisinart Inc., Greenwich, CT) for 1 min, then, corn starch was added, and the mixture was chopped for 1 min. The mixture was screened through a U.S. No. 10 sieve and mixed well again. This screening and chopping were repeated three more times. The final residue was combined with all the screened blend and stored at 4℃ in Ziploc® freezer bags to ensure moisture equilibration. Ground lean of lamb, mutton, goat meat, spent hen meat and beef were also prepared as the same procedures with starch and extruded at the optimum condition. The dried extrudates were chopped in the food processor for 30 sec to evaluate water activity, microbiological counts, and fatty acid composition.

Response surface methodology

A response surface methodology was used to optimize extrusion processing variables such as feed moisture, process temperature, and screw speed for blends containing lamb and starch and to study relationship between variables. The nonlinear effects of three independent variables on physical properties (expansion ratio, bulk density, shear force, and color) of extrudates were estimated. Extrudates were produced using a central composite rotatable design[8]. The range and center point of the three variables were chosen based on preliminary trials. Response surfaces were obtained using RSREG procedure of the Statistical Analysis System[34] program.

Extrusion cooking

A single-screw laboratory extruder (Tpye 1503) from C.W. Brabender Instruments Inc. (South Hackensack, NJ). The ranges of variables used in RSM experimental design were shown in Table 1. From those results, extrusion conditions were set at the optimum condition(Table 5) for minimal shear force values; feed speed was set at 70%, temperatures were set at 20℃ for the first barrel section, 90℃ for the second barrel section and 148℃ for the third barrel section. Screw speed was set at 134 rpm. Feed moisture level was fixed at 26.5%. Two extrusion runs (2.5kg/batch) were conducted for each meat type on two separate days (5 different meat-starch blends/day). The dried samples were placed in Ziploc® freezer bags and held at-20℃ (<4 months) until completion of all analyses.

Physical/rheological properties

Expansion ratio (ER), bulk density (BD), shear force (SF), and Hunter color (HC) determination were done as described by Park et al.[27].

Microbiological analysis

Total aerobic plate counts were determined using the procedure of American Public Health Association (APHA)[2].

Table 1 - Coded levels for independent variables used in experimental design for optimization of extrusion of sheep meat with starch

Variables	Coded level					Interval
	-2	-1	0	1	2	
Feed moisture (%)	22.9	25.8	28.7	31.6	34.5	2.9
Process temperature(℃)	140	150	160	170	180	10
Screw speed(rpm)	110	120	130	140	150	10

Water activity

Water activity (a_w) was determined using a hygrometer(Model 3080; Hydrodynamics Universal, Jessup, MD) with detachable sensors calibrated in an aw range of 0.07 to 0.18[30].

Fatty acid composition

Total lipids were extracted by the procedure of Folch et al.[12], modified by Park et al.[27]. An aliquot of the lipid extract was freed of solvent under nitrogen and methylated as described by Metcalfe and Wang[21]. Fatty acid methyl esters were analyzed by Gas chromatography.

Nutritional properties

Total fat, protein, moisture, and ash were determined by the AOAC[1] procedures. Calories per 28g serving size were calculated using 9kcal/g fat and 4kcal/g carbohydrate or protein. The saturated fat was estimated from total saturated fatty acid data (Table 8).

Sensory evaluation

An 8-member highly trained flavor/texture descriptive attribute panel at the Texas A&M University Sensory Testing Facility was utilized. Panelists had been trained using the Spectrum™ intensity scales (0-15 with reference standards) according to Meilgaard et al.[19]. The ballot was developed during the training sessions and included aromatics such as meat species flavor (beef, chicken, fish, goat, or lamb/mutton), rice, corn, wheat, dried grassy and musty.

Texture attributes included roughness (smooth/rough), fracturability (crumbly/brittle), hardness (soft/hard), denseness (airy/dense), tooth packing (nonstuck/very much stuck on the surface of teeth), and residual. Panelists were asked to first lick the surface of the product with their lips and tongue (before biting/chewing) to evaluate the roughness and asked to chew at least 20 times to evaluate tooth packing and residual. In each test session, five products were served one at a time in a random order at a 3 min interval, under red light to avoid bias due to color. Panelists were instructed to expectorate each sample after evaluation and were provided with unsalted crackers and water for cleansing/rinsing between samples.

Statistical analysis

The SAS Institute, Inc.[34] program was used for data analyses. Data were analyzed by the General Linear Model (GLM) procedure. To determine product (meat type/species) effects, data were analyzed as randomized block experiments. The Student-Newman-Keuls (SNK) test was used to separate main effect means at a significance level of $P \leq 0.05$. Sensory data were analyzed blocked by panelists, while nonsensory data were analyzed blocked by replications.

RESULTS AND DISCUSSION

Effects of extrusion variables on physical properties of extrudates

Expansion ratio (ER), bulk density (BD), shear force (SF), and Hunter color (HC) values(L) for extrudates obtained with different combinations of the extrusion variables are shown in Table 2. Regression coefficients and equations describing the responses are shown in Table 3. Feed moisture(x_1) had a linear effect on BD and SF, and quadratic effect on ER. High feed moisture resulted in high BD due to the dense areas and thick cell walls; this was also observed by Jean et al.[15]. The thicker the cell wall the greater the shear force required to break through the matrix; generally, higher shear force values for extrudates were obtained at higher feed moisture levels[40]. Various studies on extrusion of both proteinaceous and strach systems have found that puffing is inversely related to feed moisture[16),26)]. However, in this study, high feed moisture decreased ER, but this trend was not consistent at the process temprature below 150℃(run #2 and #6). At<150℃, the starch may not have been fully gelatinized in the presence of meat, and it was less able to support expansion.

Process temperature(x_2) had a linear effect on HC and quadratic effect on SF. Screw speed (x_3) had a linear and quadratic effect on SF(Table 3 and 4). Owusu-Ansah et al.[26)] determine that the breaking strength increased with increasing moisture content but the significant effect of moisture was more pronounced at high screw speeds. Chiang and Johnson[6)] reported that increasing screw speed decreased the retention time of the sample in the extruder, which presumably resulted in decreased starch gelatinization and increased shear force. Two factor interactions were observed between feed moisture and process temperature for ER and between process temperature and screw speed for SF(Table 3).

The adequacy of each model was tested by lack of fit and coefficient of determination, R^2(Table 4). The test of the lack of fit was not significant for ER and SF, but significant for BD and HC. Nonsignificance of lack of the fit for SF was important because the optimum extrusion conditions was decided on the basis of SF values from the fitted equation. However, R^2 values for the equations showed that the model was suitable for each of the response variables(ER, BD, SF, and HC).

Response surfaces

Optimum independent variable settings varied depending on variables. However, the optimum condition for extrusion was selected for minimal SF values(15kg/g), because product breaking strength is the most critical factor for the texture snack food[27)]. The optimum condition was: 26.5% feed moisture; 148℃ process temperature; and 134 rpm screw speed(Table 5).

Table 2 - Expansion ratio (ER), bulk density (BD), shear force (SF), and Hunter color (HC) with different combinations of feed moisture(x_1), process temperature(x_2), and screw speed(x_3) used in central composite rotatable second order design for response surface methodology to optimize extrusion of sheep meat with starch

Run	Coded level of variable			ER	BD	SF	HC		
	x_1	x_2	x_3		(g/L)	(kg/g)	*L* value	*a* value	*b* value
1	-1	-1	-1	1.23	513	18.8	55.4	6.09	15.6
2	1	-1	-1	1.34	641	27.7	60.2	2.49	13.9
3	-1	1	-1	1.45	499	15.8	71.5	2.53	14.9
4	1	1	-1	1.12	536	23.9	59.8	2.74	14.0
5	-1	-1	1	1.00	493	16.7	58.8	4.68	13.1
6	1	-1	1	1.45	819	26.9	65.7	2.21	13.9
7	-1	1	1	1.46	319	33.1	62.0	2.38	13.5
8	1	1	1	1.11	531	43.1	69.4	1.70	14.1
9	-2	0	0	1.74	326	12.6	68.1	2.54	14.1
10	2	0	0	1.24	495	24.8	63.5	2.37	15.0
11	0	-2	0	1.25	465	23.1	52.7	5.66	13.9
12	0	2	0	0.97	499	23.8	63.3	2.12	13.3
13	0	0	-2	1.13	605	25.6	61.3	3.17	14.9
14	0	0	2	0.94	396	39.2	54.1	3.28	13.3
15	0	0	0	0.89	460	15.2	62.1	2.79	12.5
16	0	0	0	1.00	404	14.0	62.5	2.62	14.2
17	0	0	0	0.94	468	19.8	67.9	1.95	13.8
18	0	0	0	0.99	444	14.8	63.2	2.76	14.9
19	0	0	0	0.83	416	18.8	62.9	2.70	13.8
20	0	0	0	0.99	441	21.0	67.9	3.38	15.1

Table 3 - Regression coefficients and equations for the response surface models to optimize extrusion of sheep meat with starch

Coefficients[a]	Expansion ratio	Bulk density	Shear force	Hunter color[b]
β_0	-0.0185	2.6541	1.2408	1.8062
β_1	-0.0205	0.0583***	0.0780***	0.0021
β_2	-0.0116	-0.0254	0.0250	0.0171*
β_3	-0.0137	-0.0298	0.0558**	-0.0051
β_{11}	0.0533****	-0.0033	0.0081	0.0051
β_{22}	0.0221	0.0164	0.0390*	-0.0090
β_{33}	0.0147	0.0182	0.0715****	-0.0093
β_{12}	-0.0540*	-0.0081	-0.0090	-0.0191
β_{13}	0.0149	0.0393	-0.0019	0.0124
β_{23}	0.0069	-0.0359	0.0789**	-0.0025

[a]Responses $h = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3$ where h=ER or BD or SF or HC; x_1=coded value for feed moisture, x_2=coded value for process temperature, x_3=coded value for screw speed response as $\log_{10}$ values.
[b]Hunter color *L* value.
*P<0.05; **P<0.01; ***P<0.005; ****P<0.001.

Table 4 - Analysis of variance for the fit of experimental data to response surface model for optimization of extrusion of sheep meat with starch

Source	df	Sum of square[a]			
		Expansion ratio	Bulk density	Shear force	Hunter color
Model	9	0.1117**	0.1169	0.3547***	0.0147*
Linear	3	0.0119	0.0789*	0.1572***	0.0051
Quadratic	3	0.0743***	0.0149	0.1470***	0.0053
Cross product	3	0.0255	0.0232	0.0505	0.0042
Residual	10	0.0280	0.0480	0.0494	0.0079
Lack of fit	5	0.0229	0.0550***	0.0212	0.0068*
Pure error	5	0.0051	0.0031	0.0281	0.0010
R^2		0.80	0.71	0.88	0.65

[a]With $\log_{10}$ values.

*P<0.05; **P<0.01; ***P<0.005..

Table 5 - Predicted values of independent variables for optimum response for expansion ratio(ER), bulk density(BD), shear force(SF) and hunter color(HC) to optimize extrusion of sheep meat with starch

Responses variables	Predicted values for optimum response		
	Feed moisture(%)	Process temperature(℃)	Screw speed(rpm)
ER	>34.5	>180	<110
BD	>34.5	>180	142
SF	26.5	148	134
HC	30.3	165	132

Physical properties

Extrudates containing different meat sources and starch produced at the optimum conditions for acceptable shear force values are shown in Fig. 24. Extrudates containing chicken and goat meat expanded more than the other products (Table 6). This was probably due to the fact that those two products contained less meat than other products to meet the target feed moisture. Conway and Anderson[7] found an overall decrease in expansion when soy protein products (isolate, concentrate, and flakes) were added to a yellow snack corn meal base. However, the five products in this study were not different in bulk density and shear force. Extrudates containing chicken had the highest *L* values, and extrudates containing beef had the lowest *L* values. Beef might have contained more heme pigment than other red meats, resulting in darker color, since chicken naturally contains less myoglobin than red meats, the lightness of the chicken extrudates was expected.

Water activity and microbiological analysis

Water activity for all the extrudates was very low with no differences found among the five products with different meat sources (Table 7). Total aerobic plate counts were <10 (CFU/g) for all products (Table 7). This may be because the dried extrudates had very low a_w. Thomas[40] reported that extrusion cooking for the development of meat-based snack products was very effective for destroying microorganisms. Ray et al.[31] prepared extruded jerky-type products from blends of partially defatted chopped beef, mechanically separated chicken or chicken thigh and leg meat, potato flour, and chile powder. Although raw feed materials had very high aerobic plate counts (>39,000 CFU/g), microbial counts decreased after extrusion (<200) regardless of meat source.

Fatty acid composition

The total amount of fatty acids and proportions of different fatty acids in meat differ considerably among meat animal species. Fatty acids in tissues of ruminants, such as beef, goat meat, and lamb/mutton, are more saturated because microbes in the rumen extensively hydrogenate the unsaturated fatty acids in their diets[32].

Palmitic (16:0) acid was the major saturated fatty acid and oleic (18:1) acid was the major unsaturated fatty acid for all products (Table 8). On a percentage basis, total SFA was in the order of the extrudates containing mutton>goat>lamb>beef>chicken; total MUFA, the extrudates containing

Table 6 - Experimental data on expansion ratio (ER), bulk density (BD), shear force (SF), and Hunter color (HC) for extrudates from blends of starch and different meats

Product (meat source)	ER	BD (g/L)	SF (kg/g)	HC		
				L value	a value	b value
Beef	1.43[b] (0.028)*	242[a] (25.461)	13.15[a] (0.509)	68.73[d] (1.308)	2.42[a] (0.205)	13.84[c] (0.148)
Chicken	1.55[a] (0.014)	219[a] (14.849)	14.83[a] (1.464)	77.78[a] (0.403)	1.67[c] (0.014)	17.44[a] (0.014)
Goat meat	1.54[a] (0.007)	260[a] (0.707)	15.92[a] (1.223)	75.64[b] (0.198)	0.66[d] (0.099)	13.66[cd] (0.191)
Lamb	1.43[b] (0.042)	207[a] (2.121)	12.68[a] (0.537)	72.31[c] (0.502)	1.99[b] (0.014)	14.55[b] (0.127)
Mutton	1.40[b] (0.021)	218[a] (23.335)	13.15[a] (0.863)	72.62[c] (0.205)	1.59[c] (0.035)	13.51[d] (0.021)
RSD**	0.024	17.496	1.081	0.623	0.099	0.079

[a-c]Means within a column having the same superscripts are not significantly different ($P > 0.05$).

*Standard deviation.

**RSD = residual standard deviation.

Table 7 - Aerobic plate counts and water activity for extrudates from blends of starch and different meats

Product (Meat source)	Aerobic plate count (CFU/g)*	Water activity
Beef	<10	0.112
Chicken	<10	0.107
Goat meat	<10	0.107
Lamb	<10	0.113
Mutton	<10	0.120

*Colony forming unit

beef>mutton>lamb>chicken>goat; total PUFA, the extrudates containing chicken>goat>lamb>mutton>beef. Extrudates containing chicken had the highest PUFA/SFA ratio, followed by those with goat meat, lamb, mutton and beef, whereas extrudates containing beef had the highest MUFA/SFA ratio, followed by those containing chicken or lamb, mutton, and goat meat. Ono et al.[39] (1984) reported that lamb had higher linoleic (18:2) acid and PUFA/SFA ratio than mutton; differences in fatty acid composition between extrudates containing lamb and mutton are consistent with their results. Park et al.[28] reported that PUFA/SFA ratios for longissimus dorsi and biceps femoris muscle from goats were higher than the values for the corresponding beef muscles (0.13 and 0.23)[9]. In this study, extrudates containing goat meat had higher PUFA/SFA ratios than extrudates with beef.

Nutritional properties

Data on nutritional properties of the extrudates containing starch and different meat sources are presented in Table 9. All extrudates contained similar calories, total carbohydrate, and protein. However, extrudates with chicken and goat meat were slightly lower in fat than the other products and those containing beef and mutton were slightly higher in protein because their raw material mixes prior to extrusion contained more meat. All products from this study were lower in calories, calories from fat, and total fat, but higher in total carbohydrate when compared with a similar commercial product (Chee-tos puffs; Frito-Lay, Inc.); protein contents were similar. The products from this study contained no added sodium (from salt).

Sensory properties

Overall, aromatic and taste attribute scores were not significantly different among products regardless of meat species(Table 10). Although extrudates containing beef or mutton had numerically higher meaty aromatic scores than the other products, there was no statistical differences. The rice and dried-grassy aromatics were more prevalent than other flavor notes in all samples. The panelists commented that most of the products had dried-grassy as the initial flavor note. However, the panelists detected rice aromatic more

Table 8 - Fatty acid compositions for extrudates of starch and different meats.

	%*				
	Meat source in extrudates				
Fatty acid	Beef	Chicken	Goat meat	Lamb	Mutton
14:0	2.95[b]	0.66[c]	1.26[c]	3.43[a]	1.69[c]
	(0.03)	(0.23)	(0.20)	(0.09)	(0.00)
16:0	26.48[a]	28.08[a]	28.18[a]	30.04[a]	25.52[a]
	(0.20)	(0.62)	(4.06)	(0.59)	(0.35)
16:1	3.36[a]	2.50[b]	1.66[c]	2.15[bc]	1.56[c]
	(0.15)	(0.09)	(0.39)	(0.12)	(0.03)
18:0	13.91[bc]	6.05[d]	17.06[b]	12.43[c]	21.77[a]
	(0.03)	(0.10)	(2.88)	(0.05)	(0.23)
18:1	46.13[a]	27.61[c]	27.28[c]	37.62[b]	39.43[b]
	(0.74)	(1.08)	(3.38)	(0.20)	(0.30)
18:2	4.33[d]	19.56[a]	13.61[b]	8.69[c]	5.24[d]
	(0.07)	(0.82)	(1.91)	(0.96)	(0.04)
18:3	0.10[a]	1.36[a]	1.13[a]	0.87[a]	0.39[a]
	(0.14)	(1.08)	(0.04)	(0.56)	(0.03)
20:4	2.74[a]	14.19[a]	9.81[a]	4.78[a]	4.39[a]
	(0.25)	(1.93)	(12.08)	(0.94)	(0.99)
Total SFA	43.34	34.79	46.50	45.90	48.98
Total MUFA	49.49	30.11	28.94	39.77	40.99
Total PUFA	7.17	35.11	24.55	14.34	10.02
MUFA/SFA	1.14	0.87	0.62	0.87	0.84
PUFA/SFA	0.17	1.01	0.53	0.31	0.20

[a-d]Means within the same row having the same superscripts are not significantly different ($P > 0.05$).

*Percentage based on the total peak area.

**Standard deviation.

Table 9 - Nutritional values of extrudates from blends of starch and different meats

	Values/28g serving				
	Beef	Chicken	Goat meat	Lamb	Mutton
Calories(Kcal)	109.75	111.65	109.92	111.51	111.47
Calories from fat(Kcal)	2.52	0.99	1.26	2.79	3.51
Total fat(g)	0.28 (0.43)*	0.11 (0.17)	0.14 (0.22)	0.31 (0.48)	0.39 (0.60)
Saturated fat(g)	0.12 (0.60)	0.04 (0.20)	0.06 (0.30)	0.14 (0.70)	0.19 (0.95)
Total carbohydrate(g)	25.38 (8.46)	25.90 (8.63)	25.56 (8.52)	25.86 (8.62)	25.82 (8.61)
Protein(g)	2.04 (3.40)	2.00 (3.33)	1.91 (3.18)	2.01 (3.35)	2.04 (3.40)

*Percentages(%) of a daily value for a 2,000 Kcal diet.

than corn aromatic, although the raw material blends of all products contained more than 80% of corn starch. It should be noted that when the panelists were being trained with extruded corn and rice breakfast cereals(Corn Chex and Rice Chex; Kellogg, Inc.), they gave similar scores of rice aromatic and corn aromatics for both products. Although Corn Chex is made with 100% corn, the panelists determined that its predominant flavor note was 'rice', as was for Rice Chex. It may be that extrusion cooking(with or without puffing) of corn-derived materials(including corn starch) might impart a flavor note which the panelists described as rice, the result of certain chemical changes for flavor precursors and flavor compounds that take place during extrusion cooking. Thomas[39] (1990) observed that the extrudates from blends of 20% dehydrated beef or pork, 70% potato starch, and 10% soy protein isolate produced with a flavor enhancer such as hydrolyzed vegetable proteins(HVP) had a limitation in flavor improvement. The addition of 2.5% HVP was sufficient to improve the flavor of the pork extrudates, but the beef extrudates were still bland at this incorporation level. They postulated that it may due to the volatility and relatively low stability of the flavor compounds when the products were exposed to the severe extrusion cooking. In this experiment, none of the samples had mean ratings of aromatics and tastes above 3 (on a 0-15 scale), and all products were fairly bland.

In extruded products, texture is the most important consideration since color and flavor can be easily modified to achieve product requirements. Although textures attribute scores were similar for all products, the extrudates with goat meat had higher fracturability, hardness, and denseness scores than the other products. Some panelists detected some hard and grainy particles left even after they chewed them, and they scored them as the residual. The scale values for the texture profile anchors used for the retraining sessions for this study were based on Meilgaard et al.[19]; and 5.5 for onion flavored ring for residual.

CONCLUSIONS

Optimum extrusion conditions for minimal shear forces were 26.5% feed moisture, 148℃ process temperature, and 134 rpm screw speed with a bench-top single-screw extruder. Extrudates produced at such conditions from blends of starch and various ground meats (i.e., beef, chicken, goat meat, lamb, and mutton) were generally similar in physical/rheological properties and sensory characteristics. This study shows that it is possible to extrude 16-18% fresh lean meat in a corn starch base and obtain well expanded extrudates with an appealing appearance and bland flavor which would be highly suitable for the commercial snack market. However, further reseach is needed to determine if higher meat incorporation levels are possible, with additional or other nonmeat ingredients included although the high moisture content of fresh meat could be a limiting factor for extrusion. Such nonmeat ingredients may include vegetable proteins, vegetable powders, and dietary fiber products that could also improve the overall nutritional value.

Table 11 - Sensory scores for the extruded products as affected by starch and different species meats

Sensory attribute	Beef	Chicken	Goat meat	Lamb	Mutton
Aromatic					
Meat	0.33[a] (0.51)	0.29[a] (0.49)	0.14[a] (0.39)	0.19[a] (0.49)	0.37[a] (0.59)
Rice	2.29[a] (0.45)	2.38[a] (0.41)	2.27[a] (0.53)	2.25[a] (0.47)	2.23[a] (0.43)
Corn	0.23[a] (0.43)	0.27[a] (0.45)	0.15[a] (0.37)	0.08[a] (0.27)	0.12[a] (0.33)
Wheat	0.04[a] (0.20)	0.04[a] (0.20)	0.04[a] (0.20)	0.08[a] (0.27)	0[a] (0)
Dried grassy	1.81[a] (0.87)	1.96[a] (0.75)	2.15[a] (0.76)	1.96[a] (0.65)	1.85[a] (0.67)
Musty	0.12[a] (0.33)	0.08[a] (0.27)	0.04[a] (0.20)	0.19[a] (0.49)	0.08[a] (0.27)
Texture					
Roughness	3.81[a] (0.85)	3.37[a] (0.63)	3.19[a] (0.60)	3.58[a] (0.74)	3.69[a] (0.72)
Fracturability	4.88[a] (0.91)	4.65[a] (0.81)	5.75[a] (0.97)	5.02[a] (0.75)	4.92[a] (0.93)
Hardness	5.29[a] (1.24)	5.02[a] (1.08)	6.31[a] (1.33)	5.46[a] (1.14)	5.15[a] (1.14)
Denseness	2.98[a] (0.44)	3.02[a] (0.61)	3.40[a] (0.47)	3.12[a] (0.67)	2.77[a] (0.49)
Toothpacking	5.50[a] (0.85)	5.48[a] (1.07)	5.65[a] (1.01)	5.60[a] (0.71)	5.48[a] (1.03)
Residual	5.25[a] (0.64)	5.42[a] (0.86)	5.56[a] (0.67)	5.37[a] (0.66)	5.10[a] (0.77)
Taste					
Bitter	0.50[a] (0.51)	0.58[a] (0.63)	0.54[a] (0.56)	0.50[a] (0.58)	0.54[a] (0.58)
Sweet	1.23[a] (0.38)	1.27[a] (0.43)	1.15[a] (0.37)	1.13[a] (0.30)	1.23[a] (0.47)
Salty	0.08[a] (0.27)	0.04[a] (0.20)	0[a] (0)	0.12[a] (0.33)	0.08[a] (0.27)
Sour	0[a] (0)	0[a] (0)	0[a] (0)	0[a] (0)	0[a] (0)

[a-d]Means within the same row having the same superscripts are not significantly different (P>0.05)

*Standard deviation

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