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Physical and Functional Properties of Several Extrusion-Texturized Oilseed Protein Products Containing Beef Muscle

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Abstract

The effect of defatted and dehydrated beef muscle on the physical properties of thermoplastically extruded defatted soybean, cottonseed, peanut and sunflower seed flours were investigated. To minimize the adverse effect of meat fat and to increase the mixing efficiency of the meat with defatted oilseed flours at a given moisture level, beef muscle was extracted with chloroform-ethanol(2 : 1) at 20°C and air dried. The variety of oilseed flours used had greater effects on color, expansion, bulk density, water absorption rate and textural strength of the extrudate than did the added level of defatted, dehydrated beef muscle (0 to 20% on a dry weight basis).

Key words : extrusion, oilseed, beef, functional property

INTRODUCTION

As a low-moisture continuous-flow reactor[1], extruder has widely been used during the last decade for the extrusion texturization of starch- and vegetable protein-based products like cereals, pet foods, snack foods such as cookies, pretzels, fabricated potato chips, corn/tortilla chips, meat snacks, and plant protein-based analogs[2]. More recently, the use of food extruders has continuously increased mainly because of greater demand for snack and convenience foods. At present, cereal or grain-based snacks occupy the major portions of the market, but their nutritional values are rated relatively low by many nutritionists. Accordingly, efforts have been made to substitute those products with more nutritious, low-cost snack foods which have high content of high quality proteins. The addition of beef to plant protein-based flour/grit appears to be technically and economically sound approach to achieve such goals. Due to the current relatively high cost and limited availability of beef, its use as an enrichment ingredient must be justified by possible benefits in sensorial, functional, and nutritional characteristics of extruded foods.

In spite of the extensive studies of extrusion on plant-based proteins, there is a limited number of published data[3-6] in support of understanding the interactions occurring among meat and nonmeat components of an extruded formulation. It is widely known that the texture of the resulting extruded food product is affected by the shear environment in the extruder screw and die, the time/temperature history necessary for chemical cross-linking of the molecules and the type of ingredients[1,7]. It is also revealed that proteins with certain molecular sizes and solubilities are essential for texture formation, and insoluble carbohydrate play significant roles[1,8,9].

The purpose of this research is to discover basic scientific information relating to the manufacture of texturized protein foods from meat in combination with several nonmeat protein ingredients. Since the principal plant protein products on the market today are derived from oilseed sources[10], this experiment emphasized the textural properties of products manufactured by thermoplastic extrusion of oilseeds containing slightly more than 50% protein. In order of importance, defatted soybean, cottonseed, peanut, and sunflower seed are generally recognized as the important sources of vegetable protein meals[11].

Thus, this study was conducted to determine : (1) the optimum raw material and extrusion conditions to produce beef-oilseed protein extrudates targeted to a snack-like food, and (2) physicochemical and rheological properties of the above produced products as effected by the amount of beef muscle and oilseed varieties.

MATERIALS AND METHODS

Materials

Beef top round muscle was obtained from a local meat processor and used as the animal protein source. All separable fat was removed to obtain the lean before further treatment. The beef muscle and subcutaneous fat from a beef carcass were chopped through a 0.95cm-hole plate, vacuum packed, and stored frozen until used. To obtain defatted-dehydrated beef muscle, the thawed meat was extracted with a 2 : 1 chloroform-ethanol solvent system[12], followed by air-drying and vacuum-oven drying at 45°C for 2 hours to remove residual solvent and moisture. Defatted cottonseed, peanut, and sunflower seed flours which previously had been hexane-defatted using pilot plant scale-oil milling facilities in Food Protein R & D Center, Texas A & M University and soybean flour obtained from Central Soya Co., Fort Wayne, IN, USA were used as plant based protein sources.

Extrusion operation

The meat and nonmeat blends were extruded using a single-screw extruder under the pre-optimized operating conditions as follows. Extruder-A bench type extruder from C. W. Brabender, instruments, Inc. (South Hackensack, NJ) ; Barrel-19mm diameter with L/D ratio, 20 ; Screw-Compression ratio, 4 : 1 ; Screw speed -170rpm ; Nozzle-3.2mm, I. D. ; Temperature control-Electric heating, compressed air cooling ; Feeder speed-30rpm ; and Temp Zone 1-90°C, Zone 2-170°C, Zone 3-120°C.

Analytical methods

Color

A Hunter Color Difference Meter (Model D25, Hunter Associates Laboratory, Inc., Fairfax, VA) with 5.7cm diameter sample cuvette was used, making the measurement through the bottom of the cuvette. Triplicate measurements were made of each chopped product.

Expansion ratio

Expansion ratio was calculated by dividing product diameter by die diameter[6]. Twenty measurements were made per treatment.

Bulk density

The chopped extrudate gently filled in 250ml cylinder was weighed and the weight was divided by volume. The bottom of the cylinder was repeatedly tapped gently on a laboratory bench until there was no further diminution of the sample volume. Triplicate measurements were made per treatment.

Water absorption index

Twenty grams of chopped product were fully hydrated with 100ml of distilled water for one hour at room temp with occasional stirring. After equilibration, the excess water was drained on a US #20 sieve for two min, followed by removing the residual water on a paper towel. Water absorption index was expressed as WAI=(weight gain upon hydration/dry weight)×100. Determinations were made on triplicate samples per treatment.

Shear energy

Five grams of chopped sample trapped between US #3 and US #6 sieves were placed in an Allo-Shear Press (C-15 shear shell, model S-211E) attached to Instron Universal Testing Machine (Model 45 02). Crosshead speed was set at 100mm/min and measurements were made in five replicates. The track energy required to shear the extruded products inside the shell was read by the computer system which is attached to the Instron.

RESULTS AND DISCUSSION

It has been reported that fats and oils in the raw material could interrupt the cohesive matrix[2] and/or lubricate barrel and screw surfaces inside the machine, causing the expansion rate of the extrudate drastically[11]. Extrusion trials with whole beef muscle and defatted soy flour revealed that excess fat interfered with the extrusion process, causing irregular extrusion and die head blockage. The presence of high moisture along with fat also limited the amount of meat that could be incorporated into the raw material mixture. Theoretically, the maximum amount of beef muscle containing 75% water that can be mixed with a dry soy protein ingredient for extrusion is approximately more than 27% in the final mix (w/w, as-is basis) because the water content of the entire raw material for extrusion should be adjusted to more than 20%. Accordingly, it was postulated that removal or substantial reduction of fat and moisture from meat is essential for effective moisture control of raw materials and uniform extrusion operation. The protein content of the defatted oilseed flours is in the 50 to 55% range, and only 3.8% of fat is remained in the dried meat powder (Table 1).

Effects of moisture in the feed is one of the most critical factors that governs the physical properties of the extrudate, although its generalization is not quite simple. The intrinsic functional properties such as water binding capacity and water absorption rate of oilseed proteins may also affect the extrudate properties. Principally, it is known that water instantly vaporizes, causing extrudate to expand as it comes out from the die. It is also known water functions as a heat sink and lubricant inside the extruder barrel and reduces shear[14]. On the other hand, the low moisture content of the feed material could bring the high power consumption and jamming phenomena of the material in the barrel which causes entire interruption of the extrusion operation. Through the testing operation of the extruder with the raw materials of different defatted meat and defatted oilseed flours, it was postulated that the optimal moisture content should be at around 24% for the adequate operational conditions. However the actual moisture content of moistened feed entering the extruder showed rather wide variations from 23.0 to 27.5% (data not shown) depending on the oilseed varieties and ratio of the defatted meat in the sample.

Food color is an important parameter in specification and quality control. Color of the extruded products is mostly governed by the natural pigmentation of the raw materials, but other processing variables, such as cooking temperature and expansion ratio, also will affect product color. Since all of the red blood haem and possibly most of the myoglobin pigment were removed from the muscle through the previous defatting procedure, the reddish brown colors caused by high cooking temperature of the extruder predominated in the products. The hue of all samples (Table 2) was in the red region as indicated by hue angle values ($\tan^{-1}(b/a)$). The "L" values for the control sample, in increasing order of lightness, were sunflower seed, soybean, cottonseed and peanut flours. All samples tended to be darker at higher meat level except for the sunflower flour which has an inherent dark color. The changing rate in redness was highest in cottonseed flour, with increased

Table 1. Proximate composition of raw materials*

	Moisture	Protein	Fat	Ash
Defatted oilseed flour				
Soybean	9.7	49.5	0.6	6.9
Cottonseed	5.8	57.0	0.8	7.3
Peanut	7.0	59.6	2.4	5.0
Sunflower seed	6.2	55.2	1.2	6.0
Defatted beef	7.6	77.1	3.8	1.7

*As is basis

Table 2. Color characteristics of meat/nonmeat protein extrudates

Sample	Meat : Nonmeat	L	a	b	$\tan^{-1}(b/a)$
Soybean	0 : 100	41.69	5.92	14.90	68.27
	5 : 95	42.02	5.47	14.48	69.36
	10 : 90	39.46	5.28	13.22	68.22
	15 : 85	37.49	5.34	11.98	65.97
	20 : 80	33.28	5.10	10.00	62.96
Cottonseed	0 : 100	46.99	1.44	12.93	83.64
	5 : 95	43.16	1.97	12.34	80.92
	10 : 90	41.87	2.17	11.93	79.68
	15 : 85	42.90	2.17	12.03	79.76
	20 : 80	42.15	3.08	12.27	75.89
Sunflower seed	0 : 100	38.63	8.30	10.61	51.78
	5 : 95	40.08	6.80	10.40	56.83
	10 : 90	37.97	6.44	9.97	57.13
	15 : 85	38.67	6.40	10.67	59.04
	20 : 80	42.84	5.28	10.54	63.38
Peanut	0 : 100	46.88	3.16	12.29	75.57
	5 : 95	46.45	3.46	12.78	74.84
	10 : 90	46.32	3.61	12.86	74.31
	15 : 85	45.53	3.76	12.29	72.99
	20 : 80	43.78	4.59	12.93	70.47

"a" value by more than two folds at 20% substitution of meat. With increasing amounts of the meat, the hue value turned more reddish ; sunflower products again showed the opposite. The inherent dark color of sunflower flour prior to extrusion resulted in the less reddish extrudate with the addition of light colored meat powder.

Heat and mechanical work during the extrusion process change the native, organized tertiary structure by exposing bonding sites which lead to cross-linking and a reformed, expandable structure[1]. Extrudates containing more meat puffed less than those containing less meat (Fig. 1). This tendency was more clear with the oilseeds which inherently expand easily (at 0% meat substitution) as shown in cottonseed and sunflower seed samples. The inherent nature of beef muscle having a poor puffing ability upon exiting from the die adversely affected the expansion of the extrudate. Thus, the differences in the degree of expansion among oilseed samples are markedly narrowed at 20% meat substitution. It is postulated that meat and oilseed protein layers were subjected to some physicochemical reactions inside the barrel, and evaporating moisture was not effectively captured by the newly formed protein structures when the pressure is released at the die. However, which component of oilseed and/or meat influences the change in expansion is not known at this time. Among the different oilseed products, cottonseed expanded the most, followed by sunflower seed, peanut and soybean products.

The addition of defatted meat to defatted oilseed flours generally resulted in a slight increase in bulk density from the control samples except for cottonseed flour (Fig. 2). Even though expansion ratio is quite markedly decreased by the added meat, bulk density was not affected much. This indicates that, upon extrusion, meat protein changes into lighter but more dense component whether the meat was extruded alone or in combination with oilseed components. Soybean products showed rather high values at higher meat levels, showing the highest bulk density at 20% meat (Fig. 2). Bulk density of the cottonseed flour sample, which had the highest expansion ratio, decreased over the range of meat inclusion.

Fig. 3 and 4 show the correlation between the force and total energy to shear and the level of the defatted, dehydrated meat for the extrudates. Shear force values were not correlated with the meat level up to 20% (w/w, dry weight basis). The defatted meat prepared by Folch lipid extraction[12] was a fine powder in its raw form prior to mixing with defatted oilseed flours. A substantial amount of connective tissue was screened out along with other hardly breakable materials before mixing with defatted flours. For this purpose, the raw material fed into extruder was screened to pass a US sieve #14 for better mixing and uniform feeding into the extruder barrel which is highly desirable for more stable operation of the extruder. Accordingly, typical fibrous meat structures which could bring higher resistance against shear did not give any significant effect on the shear force

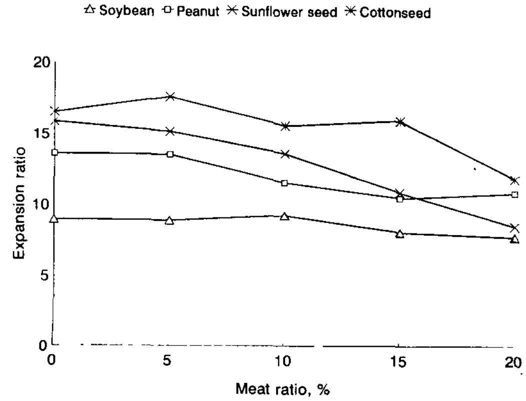

Fig. 1. Effects of the meat-nonmeat ratio on the expansion ratio of the extrudates.

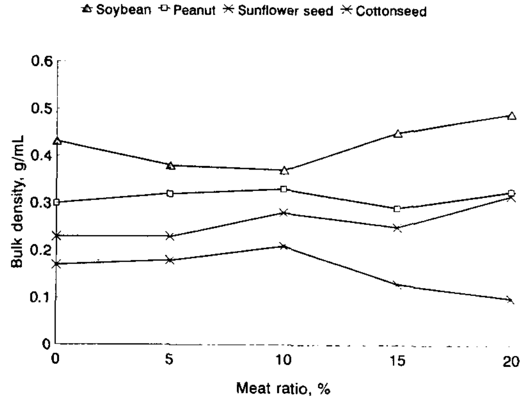

Fig. 2. Effects of the meat-nonmeat ratio on the bulk density of the extrudates.

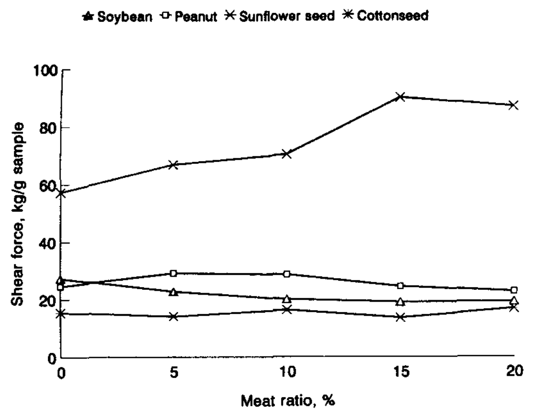

Fig. 3. Effects of the meat-nonmeat ratio on the force used to shear of the extrudates.

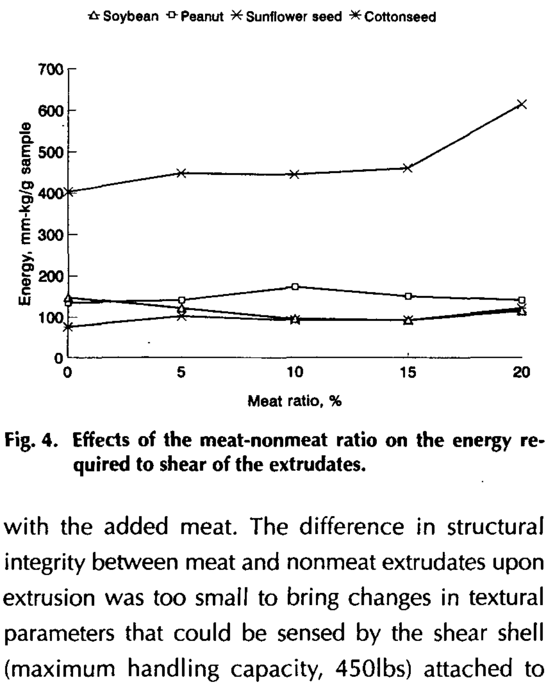

Fig. 4. Effects of the meat-nonmeat ratio on the energy required to shear of the extrudates.

with the added meat. The difference in structural integrity between meat and nonmeat extrudates upon extrusion was too small to bring changes in textural parameters that could be sensed by the shear shell (maximum handling capacity, 450lbs) attached to Instron Universal Testing Machine. According to the meat ratios, sunflower seed products required almost three to four times more force and four to six times more energy to shear than other products which showed similar shear values.

Extruded products usually possess water-holding capacities, i.e., the ability to physically hold water against gravity[15]. The ability of the extrudates to absorb water showed no consistent pattern according to the meat inclusion level (Fig. 5). Differences in the water absorption ratio among the oilseed products were also negligible except the sunflower seed products which showed twice as high a hydratability

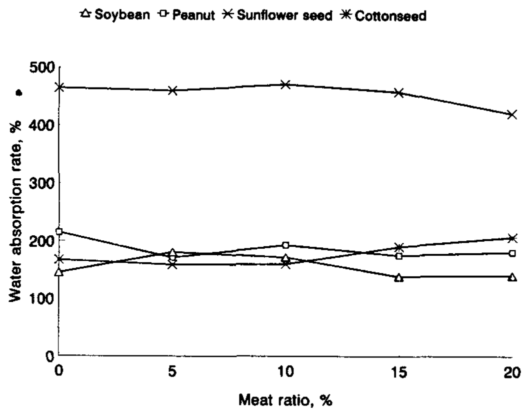

Fig. 5. Effects of the meat-nonmeat ratio on the hydratability of the extrudates.

as others. The highly porous but strong internal structures of the sunflower seed product, as indicated by lower bulk density and higher shear energy values, gave a substantially greater ability to trap and hold water physically than others.

Finally, it was generally concluded that (1) defatted and dehydrated beef powder could be incorporated into selected defatted oilseed flours at as high as 20% level (w/w, dry weight basis) without causing additional operating problems of a single-screw extruder, (2) the incorporated meat had no substantially noticeable effects on the shape, color, expansion ratio, bulk density, hydratability, and textural strength of the extrudate up to 20% level, (3) cottonseed and peanut products expanded less as the meat content increased, especially at above 15% level, (4) sunflower seed and soybean products showed less dependency on the meat level up to 20% on a dry weight basis, (5) generally cottonseed and sunflower seed flours expanded better than peanut and soybean flours at low meat level (below 15%), but the difference became very small at 20% meat level, and (6) defatted cottonseed, peanut, and sunflower seed flours could also be used as nonmeat protein sources for production of the snack-like extrudates along with defatted soybean flour, which is most commonly used now provided that sensory and nutritional requirements are identified.

REFERENCES

1. Harper, J. M. : Extrusion texturization of foods. *Food*

Technol., **40** (3), 70 (1986)
2. Lusas, E. W. and Rhee, K. C. : Extrusion processing as applied to snack foods and breakfast cereals. Ch. 16. In "*Cereals and legumes in the food supply*" Dupont, J. and Osman, E. M.(eds.), Iowa State University Press, Ames, Iowa, p.201 (1987)
3. Rhee, K. C., Kuo, C. K. and Lusas, E. W. : Texturization. In "*Protein functionality in foods*" ACS Symposium Series No. 147, Cherry, J. P.(ed.), American Chemical Society, Washington D. C., p.55 (1981)
4. Alvarez, V. B., Smith, D. M., Morgan, R. G. and Booren, A. M. : Restructuring of mechanically deboned chicken and nonmeat binders in a twin screw extruder. *J. Food Sci.*, **55**, 942 (1990)
5. Lawrie, R. A. and Ledward, D. A. : Texturization of recovered proteins. In "*Upgrading waste for feeds and food*" Ledward, D. A., Taylor, A. J. and Lawrie, R. (eds.), Butterworth & Co. Publishers Ltd., Sevenoak, Kent, England, p.163 (1983)
6. Mittal, P. and Lawrie, R. A. : Extrusion studies of mixtures containing certain meat offals : Part 1. Objective properties. *Meat Sci.*, **10**, 101 (1984)
7. Mittal, P. and Lawrie, R. A. : Extrusion studies of mixtures containing certain meat offals : Part 2. Texture properties. *Meat Sci.*, **16**, 143 (1986)
8. Taranto, M. V., Cegla, G. F. and Rhee, K. C. : Morphological, ultrastructural, and rheological evaluation of soy and cottonseed flours texturized by extrusion and nonextrusion processing. *J. Food Sci.*, **43**, 973 (1978)
9. Kazemzadeh, M., Diehl, K. C., Rhee, K. C. and Dahm, P. F. : Mechanical and structural evaluation of texturized soy proteins of varying protein content. *Cereal Chem.*, **63**, 304 (1986)
10. Breene, W. M. : Problems in determining textural properties of textured plant protein products. *Food Technol.*, **31** (4), 95(1977)
11. Aguilera, J. M., Rossi, F., Hiche, E. and Chichester, C. O. : Development and evaluation of an extrusion texturized peanut protein. *J. Food Sci.*, **45**, 246(1980)
12. Folch, J., Lees, M. and Stanley, G. H. S. : A simple method for the isolation and purification of total lipids from animal tissues. *J. Biol. Chem.*, **226**, 497 (1957)
13. Maxwell, D. : The impact of ingredients upon extruder performance. *Prepared Foods*, **8**, 177(1988)
14. Lawton, B. T., Henderson, G. A. and Derlatka, E. J. : The effects of extruder variables on the gelatinization of corn starch. *Can. J. Chem. Eng.*, **50** (4), 168 (1972)
15. Kinsella, J. E. : Functional properties of soy proteins. *J. Am. Oil Chem. Soc.*, **56** (3), 249 (1979)

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탈지 유지종자와 우육단백질을 동시에 가압사출시킨 제품의 물리 및 기능적 특성

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요 약

대표적 유지종자원료인 대두, 목화씨, 땅콩, 해바라기씨 탈지박에 지방을 제거한 후 건조시킨 쇠고기를 5~20%의 첨가함량범위로 섞어 가압사출방법을 이용하여 성형시킨 제품의 기능적 성질을 포함한 물리적 특성을 조사하였다. 가압사출이 가능한 원료의 수분 및 지방함량의 범위내에서 쇠고기 단백질의 첨가량을 늘리고 또 원료를 균일하게 혼합하기 위해 쇠고기의 지방을 혼합유기용매로 추출한 후 건조시켜 원료로서 사용하는 방법을 시도하였다. 식물성 및 동물성단백질을 동시에 가압사출시킨 제품의 팽창정도, 밀도, 조직특성, 수화능력, 색 등은 가압사출기의 작동이 원활하게 이루어지는 것으로 확인된 20%의 첨가범위 이내에서 동물성단백질의 첨가함량보다 유지종자품종에 따라 더 많은 영향을 받았다.