THE EFFECT OF HEAT TREATMENT ON AGGREGATION AND GELATION OF PEANUT/MILK PROTEIN BLENDS[1]

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ABSTRACT

Heating 10% protein dispersion of whey protein concentrate and blended systems of peanut protein concentrate or peanut flour with whey protein induced gelation at 100° C. Similarly prepared dispersions of sodium caseinate, calcium caseinate, nonfat dry milk, and blends of these proteins with peanut protein did not gel with heating. A protein concentration of 5.0% or greater was required to form whey protein gels. Gel strength of 10% protein dispersions containing peanut protein blended with whey protein at greater than 50% of the total protein was lower than was gel strength of dispersions containing more peanut protein. Addition of 0.1 to 0.2*M* NaCl or 30 m*M* $CaCl_2$ did not affect qualitative gel strength of whey protein concentrate. Gel strength of peanut protein preparations and peanut/whey blends was reduced with addition of NaCl. Addition of 30 m*M* $CaCl_2$ destroyed gelation of peanut protein, causing precipitation. Gelation of peanut/whey protein blends was less affected by the presence of $CaCl_2$ than by NaCl. While increasing the pH from 7.0 to 10.0 did not affect gel strength of whey protein, gel strength of peanut protein and peanut/whey protein blends decreased with increased pH. The viscosity of 10% protein dispersions of nonfat dry milk did not increase with heating at 100° C for 30 min. Similar heating resulted in increased viscosity of calcium caseinate, peanut flour, and peanut lipoprotein concentrate. The viscosity of sodium caseinate decreased with heating. Increases in viscosity with heating were observed for peanut lipoprotein concentrate/calcium caseinate and nonfat dry milk blends and for peanut flour/nonfat dry milk blends. The viscosity of peanut flour/calcium caseinate blends did not increase with heating. Heat treatment lowered the viscosity of peanut/sodium caseinate blends.

Formulation of peanut/milk protein blends may be a technique for expanding the use of peanut proteins. These blended food ingredients could be of superior nutritional and sensory quality to either protein individually. Presence of peanut protein, however, may alter desired functionality of milk proteins.

An important functional property of milk proteins is their ability to aggregate or thicken and gel with heat treatment (1-3). While undesirable in the storage of condensed milk (4), heat-induced aggregation or gelation or both is important to the structure of many cultured dairy systems (5). Moreover, the ability to form gels with heating could be important in many formulated foods or in nonconventional dairy products. In this study, the effects of heating on the aggregation and gelation of selected peanut/milk protein systems was investigated.

MATERIALS AND METHODS

Protein Preparations

Peanut protein preparations included commercial peanut flour (PF)[2] and a peanut lipoprotein concentrate (PLPC) that was prepared in our laboratory by a modification of the aqueous extraction procedure of Rhee *et al.* (6). Milk protein

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[2]Goldkist, Inc., Atlanta, GA.

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preparations included a whey protein concentrate (WPC) (Enrpro-50),[3] sodium caseinate, calcium caseinate,[4] and commercial nonfat dry milk (NFDM). Peanut protein preparations were dry blended with the milk proteins at levels of 10, 25, 50, and 75% of total protein. Controls contained all-peanut or all-milk protein. Proteins were suspended in distilled water at 2.5, 5.0, 7.5, and 10.0% protein concentration was adjusted to a pH of 9.0 with sodium hydroxide and stirred for 30 min at 30°C. The pH was then adjusted to 7.0, and the suspensions were equilibrated at room temperature.

Gelation Experiments

Heating was done at 100° C for up to 30 min in a constant temperature oil bath. Time of gelation and semiqualitative gel strength was determined according to a modification of the procedure that Pour-El and Swenson (7) described. Portions of a protein dispersion (3 ml) were heated in screw-capped test tubes (150 × 16 mm). At 30-sec intervals, a test tube was removed, placed in an ice bath, and equilibrated for 3 hr at 25° C. Gel strength, which was determined on five replicates, was evaluated on a scale of 0 to 5 relative to ease of breakage by hand shaking. Representative standard gels were prepared from WPC for comparison (Fig. 1).

[3]Stauffer Chemical Company, Rochester, MN.
[4]DMI, Inc., Louisville, KY.

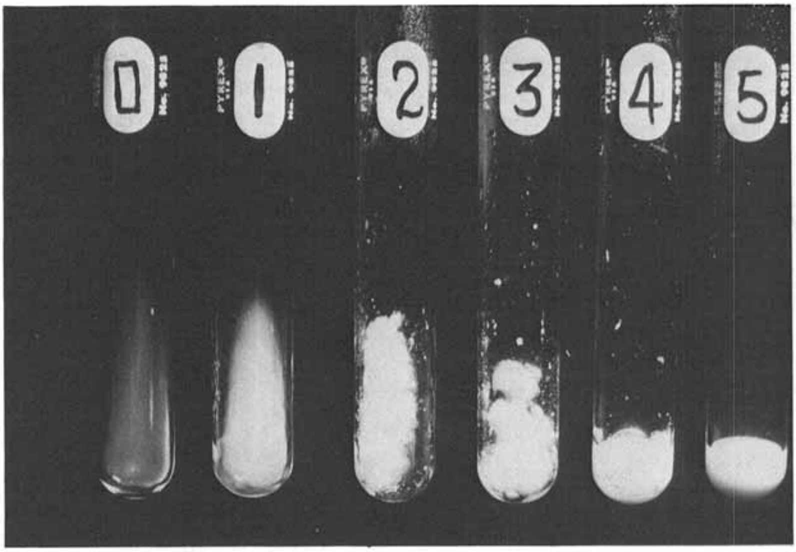

Fig. 1. Standard whey protein gels rated on semiqualitative rating scale of Pour-El and Swenson (7): 0 = no gel (liquid), 1 = very weak gel (viscous), 2 = weak gel (clumpy), 3 = medium gel (clumps stick together), 4 = good gel (hard to break up), 5 = strong gel (withstands shaking).

Viscosity Experiments

Viscosity measurements were made to determine the effect of heat on aggregation in protein systems that did not form strong gels. Protein suspensions (10%) were heated in round-bottom flasks that were fitted with Snyder columns at 100° C for 10 and 30 min. After cooling to 21° C, viscosity was determined with a Brookfield LVF viscometer. Spindle No. 3 accommodated the range of viscosities encountered. Brookfield data were obtained after 30 sec at 30 rpm.

RESULTS AND DISCUSSION

Gelation of Peanut and Milk Protein Systems

Under the conditions used in these experiments, strong gels were attainable only with WPC and some of the peanut/WPC blends (Table I). This was not surprising, since higher protein concentrations are required for gelation of reconstituted NFDM systems (1,2) and caseinate dispersions do not form gel structures readily with heating (8,9). The PLPC dispersions and PLPC/milk protein systems generally formed stronger gels than did PF dispersions and PF blended systems. Apparent gel strength rating of PLPC and 50/50 PLPC/WPC blends was 3.0 and 5.0, respectively, compared with a rating of 2.0 and 4.0 for similarly prepared PF and PF/WPC blends.

TABLE I
Gelation of 10% Protein Dispersion of Peanut Protein, Milk Protein, and Peanut/Milk Protein Blends

Protein System	Gel Strength[a]
Milk proteins	
Whey protein concentrate (WPC)	5.0
Sodium caseinate (NaCas)	0.0
Calcium caseinate (CaCas)	0.0
Nonfat dry milk (NFDM)	0.5
Peanut proteins	
Peanut lipoprotein concentrate (PLPC)	3.0
Peanut flour (PF)	2.0
Blended systems[b]	
PLPC/WPC	5.0
PLPC/NaCas	1.5
PLPC/CaCas	1.0
PLPC/NFDM	1.0
PF/WPC	4.0
PF/NaCas	0.5
PF/CaCas	0.5
PF/NFDM	0.0

[a]Measured after 30 min at 100° C. Average of two judges' interpretation of five replicates. (Rating scale of 0 to 5.)
[b]50/50 Blends.

Gels formed from WPC and peanut/WPC were irreversible and did not liquefy with further heating. Heat treatment at 100° C for greater than 30 min, however, did tend to brown and dry out the gel surfaces. Gels that contained peanut protein had more visible syneresis than did gels formed from WPC.

Peanut/Whey Protein Blends

Results of the protein concentration effect on gelation of WPC are summarized in Table II. Gel time, which was defined as the time required for formation of a strong gel (a rating of 5.0), was most affected by altering the protein concentration. Whey protein dispersions at 5.0% protein concentration required 30 min at 100° C to form a strong gel. Increasing the protein concentration to 7.5% reduced gel time at 100° C to 5.0 min. Ten percent WPC dispersions gelled in 2.0 min at 100° C. While no differences in qualitative gel strength were apparent with varied WPC concentration, gels formed from 5.0% protein dispersions were more translucent in appearance than were gels formed with higher protein content. Whey protein dispersions containing 2.5% protein did not gel

Data on effect of blending peanut protein with WPC on gel strength of 10% protein dispersions after heating at 100° C for 30 min are presented in Table III. PLPC/WPC blends formulated with PLPC at 50% or less of total protein formed strong gels (5.0 rating) with heating, while addition of PLPC to a 75% level decreased gel strength to that of a weak gel (3.0 rating). PF/WPC blends at 25% PF formed strong gels with heating, while good gels (4.0 rating) were formed by heating blends containing 50% PF. Increasing the level of PF lowered gel strength to that of a weak gel (3.0 rating).

The effect of ionic strength on gelation of whey protein, peanut protein, and their blended systems at 10% protein concentration is summarized in Table IV. Increasing NaCl to 0.2*M* or $CaCl_2$ to 30 m*M* has no apparent effect on gel strength of the WPC. Hermansson and Akesson (9) reported that viscosity of WPC dispersions heated at 80° C reached a maximum in the presence of 0.5*M*

TABLE II
Effect of Protein Concentration on Gelation of Whey Protein Concentrate

Protein Content %	Gel Time[a]	Gel Strength[b]
2.5	NG[c]	0.0
5.0	30.0	5.0
7.5	5.0	5.0
9.0	3.0	5.0
10.0	2.0	5.0

[a]Heating time (min) required at 100° C for the formation of a strong gel.
[b]Determined after 30 min at 100° C. Average of five replicates. (Rating scale of 0 to 5.)
[c]NG = no gel formed.

NaCl. Differences in WPC preparation and experimental conditions, however, make comparison difficult. Viscometric differences that are not detectable by visual evaluation conceivably do exist.

Addition of salts appeared to affect gelation of peanut protein considerably. Addition of 0.2*M* NaCl to PLPC or PF dispersions virtually destroyed any gelation of these proteins. Addition of NaCl apparently affected the PF/WPC blends more than it did the PLPC/WPC blends. Addition of 30 m*M* $CaCl_2$ destroyed gelation of PF and PLPC and caused precipitation. Good gels were

TABLE III
Effect of Increasing Peanut Protein in Peanut/Whey Protein Blends on Gelation of 10% Protein Dispersions

Protein System	Peanut Protein % of total	Gel Strength[a]
Peanut lipoprotein/whey protein	0	5.0
	25	5.0
	50	5.0
	75	3.0
	100	3.0
Peanut flour/whey protein	0	5.0
	25	5.0
	50	4.0
	75	3.0
	100	2.5

[a]Determined after heating at 100°C for 30 min. Average of two judges' interpretation of five replicates. (Rating scale 0 to 5.)

TABLE IV
Effect of Ionic Strength on Gelation of 10% Protein Dispersion of Whey Protein, Peanut Protein, and Whey/Peanut Protein Blends

Protein System	NaCl (*M*)			$CaCl_2$ (m*M*)
	0	0.1	0.2	30.0
	Gel Strength[a]			
Whey protein concentrate (WPC)	5.0	5.0	5.0	5.0
Peanut lipoprotein concentrate (PLPC)	3.0	1.0	1.0	ppte[b]
Peanut flour (PF)	2.0	1.0	1.0	ppte
Blended systems[c]				
PLPC/WPC	5.0	4.0	4.0	4.0
PF/WPC	4.0	4.0	3.0	4.0

[a]Determined after 30 min at 100°C. Average of five replicates. (Rating scale 0 to 5.)
[b]Precipitated to bottom of tube. No gel.
[c]50/50 Blends.

formed in peanut/WPC blends in the presence of 30m*M* calcium that contained PF or PLPC at 50% or less of total protein.

Increasing pH from 7.0 to 10.0 had no apparent effect on gel strength of WPC at 10% protein concentration (Table V). The gel strength of the PLPC heated under similar conditions reduced from a 3.0 to a 1.0 rating when pH was increased from 9.0 to 10.0, respectively. PF tended to maximize in gel strength when heated at a pH of 9.0. Strong gels were attained in PLPC/WPC blended protein systems heated at a pH of 7.0 and 9.0, while the PF/WPC blend gelled only at a pH of 7.0. Increasing the pH to 11.0 destroyed gelation of the proteins investigated.

Viscosity Experiments

The initial viscosity of 10% protein dispersions of NFDM and calcium caseinate was quite low, while that of sodium caseinate was higher (Table VI). Differences between the caseinate systems are not unusual, since wide variations exist in the viscosity of commercial caseinates (10). Calcium caseinate systems may be lower in viscosity than are sodium caseinate systems due to the formation of a more compact aggregate structure (11). Generalizationns should not be made, however, since the role of calcium on casein viscosity is not fully understood. Beeby and Kumetat (12) suggested that a critical level of calcium exists at which viscosity of casein is maximal at a specified pH.

The viscosity of calcium caseinate increased considerably with heat treatment, indicating formation of colloidal casein aggregates. The reverse was true of sodium caseinate in which viscosity lowered with heating. These data suggest that the unheated sodium caseinate dispersions existed as swollen protein molecules that were more dispersed after heating. Viscosity of NFDM decreased slightly with moderate heating followed by a slight increase with further heating. Heating increased viscosity of peanut proteins considerably, with an approximately tenfold increase in the viscosity of PLPC and PF after 10 min.

Blends of PLPC with calcium caseinate and NFDM increased in viscosity with

TABLE V
Effect of pH on Gelation of 10% Protein Dispersions of Whey Protein, Peanut Protein, and Whey/Peanut Protein Blends

	pH			
Protein System	**7.0**	**9.0**	**10.0**	**11.0**
		Gel Strength[a]		
Whey protein concentrate (WPC)	5.0	5.0	5.0	1.0
Peanut lipoprotein concentrate (PLPC)	3.0	3.0	1.0	0.5
Peanut flour (PF)	2.0	3.0	2.5	1.0
Blended systems[b]				
PLPC/WPC	5.0	4.0	1.0	0.5
PF/WPC	4.0	3.5	3.5	1.0

[a]Measured after 30 min at 100°C. Average of two judges' interpretation of five replicates. (Rating scale 0 to 5.)
[b]50/50 Blends.

heating at 100° C. Viscosity increases of the blended systems, however, were not of the magnitude observed with PLPC. The viscosity of PLPC/sodium caseinate blends decreased with heating.

PF/NFDM and sodium caseinate blends followed a similar trend with respect to heating effect on viscosity as did PLPC blends that were similarly formulated. PF/calcium caseinate blends, however, did not increase in viscosity with heating as did PLPC/calcium caseinate blends.

CONCLUSIONS

Gelation experiments indicate that moderate amounts of peanut protein could be incorporated into whey protein gels without destroying gel strength. Differing response of blended protein systems with respect to the effect of heating on viscosity indicate that blending to desired viscometric properties may be possible with peanut protein/milk protein preparations. Peanut/sodium caseinate blends could be used as ingredients when low viscosity with heating is desirable, while the systems that are formulated with calcium may be applicable when higher viscosity is desirable. Additional research will be necessary to explain specific interactions involved in the formation of peanut protein/milk protein aggregates or gels with heating.

TABLE VI
Effect of Heat Treatment on Viscosity of 10% Protein Dispersion of Milk Protein, Peanut Protein, and Milk/Peanut Protein Blends

Protein System	Heating Time[a]		
	0	10	30
	Apparent Viscosity[b]		
Milk proteins			
Nonfat dry milk (NFDM)	40	16	48
Calcium caseinate (CaCas)	32	96	400
Sodium caseinate (NaCas)	158	24	OSL[c]
Peanut proteins			
Peanut lipoprotein concentrate (PLPC)	168	1788	OSH[d]
Peanut flour (PF)	117	1088	OSH
Blended systems[e]			
PLPC/NFDM	144	160	320
PLPC/CaCas	80	120	1376
PLPC/NaCas	189	64	OSL
PF/NFDM	48	32	52
PF/CaCas	146	32	80
PF/NaCas	170	48	112

[a]Heating time (min) at 100°C.
[b]Apparent viscosity (cP) at 21°C on Brookfield LVF-Spindle No. 3. Measured after 30 sec at 30 rpm.
[c]OSL = Off-scale low.
[d]OSH = Off-scale high.
[e]50/50 Blends.

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