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The effect of protein additives on emulsion stability in meat systems

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Introduction

In recent years, there has been an increase in the use of protein additives in meat products, primarily because of their functional contributions. Proteins from many sources such as oil-seeds, (Burrows et al. 1972), plants, (Bird, 1975), micro-organisms, (Tannenbaum, 1968) and of animal origin have been assessed for functional abilities. Soybean and milk protein are by far the most important sources. Soya isolates have a high level of functionality and are used successfully in meat products. They exhibit a higher viscosity than milk proteins at the same concentration (Hermansson, 1975), and increases in emulsifying capacity have been shown to be directly related to increases in viscosity (Carpenter and Saffle, 1965). Contradictory reports by Pearson et al. (1965) and Inklaar and Fortuin (1969) on the superiority of either caseinate or soya isolate as an emulsifying agent are explained by differences between emulsifying capacity and emulsion stability produced with proteins as well as by variations in the efficiency of emulsification due to the equipment and times used (Tornberg and Hermansson, 1977).

Soluble whey protein concentrates have also attracted attention as a potential ingredient of formulated meat preparations such as meat loaf and sausage (Lauck, 1975, Moore et al. 1976). The emulsification capacity of whey protein has been studied (Morr et al., 1973). However, the whey protein concentrates exhibit inferior emulsification properties in comparison to caseinate. A new milk protein additive isolated recently consists of undernatured whey proteins co-precipitated with the acid-insoluble proteins. The co-precipitated proteins have functional properties superior to blends of the two proteins or whey proteins alone, with foaming and emulsifying properties similar to sodium caseinate (Connolly, 1982).

The aim of this presentation is to study the viscosity and gelation of milk protein and soya protein additives and to correlate these functional properties with cooking losses and emulsion stability. Microscopial examination of some of the emulsions was also undertaken in an effort to correlate structure with cooking losses.

Materials and Methods

The following protein additives were used: Soya Isolate, (81.5% protein); Sodium Caseinate I, (85.5% protein) High viscosity; Sodium Caseinate II, (83% protein) High viscosity; Sodium Caseinate III, (85.1% protein) Normal viscosity; Whey Protein Concentrate, WPC (70% protein); Wheat Gluten, (65.5% protein); Total Milk Protein, TMP.

Pork Fatty Tissue - Fresh pork back fat was chopped at slow speed in a bowl chopper for 10 seconds and held at 5°C until used, smaller quantities were held at -20°C until required and then thawed at 5°C prior to being used.

Viscosity Test - Protein dispersions of known percentage protein were prepared in distilled water at 60°C, tempered at 15°C overnight and viscosity measurements were made with a Brookfield Synchro-Lectric viscometer model RVT after 30 seconds shearing at a spindle speed of 100 rpm.

Gelling Test - Samples were placed in plastic containers and held at room temperature (20°C) for 1 hour or heated to 80°C in a water bath for 1 hour and then held at 5°C for three days. Gel strength is defined as the force required to drive a metal probe with diameter 1.2 cm (area = 1.131 cm^2) into a sample to a depth of 1.0 cm using an Instron Universal Testing machine, Model TM-M. The Instron was equipped with a 2 kg compression load cell and set at a full scale force of 2 kg. The crosshead speed and paper speed was 20 cm/min and 10 cm/min respectively.

Preparation of Emulsions - Pre-formed emulsions were prepared in a 2 speed Muller 20-litre bowl chopper (2,300 rev/min and 2,600 rev/min) using a 5:5:1, fat:water:protein recipe. Batches of 9.1 kg total weight were made. The protein was hydrated for 2½ minutes. Pork back fat was then added and chopped at high speed for 1.5, 2.5, and 4.5 minutes with samples being removed after each chopping time.

Emulsion Stability: (a) Frying - A known weight of emulsion was transferred on cooking foil into a Sunbeam 'Multicooker' frying pan maintained at 172°C ± 1°C and cooked for 10 minutes. The final weight of cooked material was measured, any separated fat was absorbed by tissue paper and its weight recorded. The water loss was obtained by difference and the percentage losses calculated. (b) Sterilisation - The prepared emulsions were weighed accurately into tared 5 oz. cans (210 x 204). The cans were seamed and heat processed in a Hearson laboratory autoclave for 30 minutes at 15 lb per square inch pressure. On cooling the contents to 45°C, the cans were opened and any separated water and fat was drained into tared tubes. The can contents and tubes were stored overnight at 5°C, weighed and percentage fat and water losses calculated. (c) Pasteurisation - A known weight of emulsion was filled into tared 5 oz. cans (210 x 204). The cans were seamed and pasteurised in a water bath at 80°C to an internal temperature of 72°C and treated as for sterilisation above.

Measurement of Hardness and Cuttability - An Instron Universal Testing machine, Model TM-M equipped with a 2 kg compression load cell and set at a force of 500 g was used to measure both hardness and cuttability of uncooked emulsions. The crosshead speed and paper speed was 3 cm/min and 10 cm/min respectively. All samples were kept at 5°C prior to and during testing.

The hardness of an emulsion was measured as the force required to drive a metal probe (1.18 cm diameter, area = 1.131 cm^2) into a sample (6 cm diameter x 1.5 cm high) to a depth of 1.0 cm. Cuttability was measured as the force required to cut a sample (7 cm diameter x 2 cm high) to a depth of 1.0 cm using a taut metal wire (0.06 cm diameter) as a blade.

Measurement of Colour - Colour was measured using a Hunterlab Digital Colour Difference Meter, Model D25D2A. The three colour coordinates were L, a and b.

Results

Viscosity is dependant on the type (Table 1) and the concentration (Fig. 1) of protein isolate used. Caseinates type I and II show the highest viscosity readings with soya isolate at an intermediate level. Normal caseinate, TMP and WPC show the lowest readings. The viscosity profiles over a range of protein concentrations are shown in Figure 1. With increasing protein concentrations above 9% there are large linear logarithmic increases in viscosity, in particular for TMP, Caseinates type I and II and soya isolate, the latter having the highest viscosity at lower protein concentrations.

Gel strengths of the protein isolates at 15% and 20% concentration were measured after heat treatments at 20°C and 80°C for 1 hour (Table 2). The WPC had the best gel strength after the 80°C x 1 hr. treatment whereas the soya isolate had highest gel strength at 20°C x 1 hr. heat treatment. In general, the higher the protein concentration and the higher the heat treatment the stronger the gel strength for all proteins. Soya isolate with no heat treatment had better gelling ability than any of the caseinates.

Emulsion stability during heat processing was measured using fat loss as an indicator, and it was considered stable if fat losses were less than 2% of the fat originally added. A summary of cooking losses for the various protein isolates and cooking conditions is shown in Table 3. For emulsion stability; with sterilisation - gluten and TMP were unacceptable; with pasteurisation - gluten was unacceptable; with frying - all but soya isolate were considered to be unacceptable.

Of the three heat treatments, frying resulted in the highest fat losses and emulsion collapse in 6 out of 8 proteinates. As expected frying also resulted in high water losses. Chopping time is important for emulsion stability, under-chopping and over-chopping must be avoided. Of the two emulsions stable to frying, the soya isolate was best with slight reductions in fat losses from 1½ to 4½ minutes chopping time (Table 4). Gluten, however, showed increased fat losses with time.

Chopping times also affect moisture losses as outline in Table 4. Chopping times of up to 4½ minutes gave reduced losses. Soya isolate had lowest moisture losses and Caseinate type III the highest.

The effect of fresh versus frozen fatty tissue on moisture losses with various chopping times was investigated using a Caseinate type II emulsion (Table 5). Frozen fatty tissue resulted in the highest moisture losses but were reduced with chopping times of up to 4½ minutes.

Hardness and cuttability were also determined on uncooked emulsions from the various proteinates and at varying chopping times (Table 6). Both measurements increased with chopping time for all proteins except WPC and Gluten. Caseinate type I was the hardest of the emulsions formed. Colour of the formed uncooked emulsion was also measured (Table 7). and was found to increase in whiteness (b units) with chopping time. Caseinates gave the highest L units and lowest b unit reading with Gluten and WPC the lowest L unit and highest b unit readings.

Results from this study show that cooking losses from emulsions are indicative of emulsion stability and can be used to determine the suitability of protein additives as emulsifiers. High viscosity and good gelation also exert an influence on emulsion stability. Sodium caseinate and soya isolate were considered to be the most suitable protein additives for emulsion manufacture.

Table 1 - Viscosity of the Protein Isolates at 15°C

	Protein Concentration (%)	Viscosity (cP)
Soya Isolate	12	12,640
Caseinate I	12	>40,000
Caseinate II	12	>40,000
Caseinate III	12	1,259
TMP	12	1,995
WPC	12	28.94

Table 2 - Gel Strength of the Protein Isolates

	Gel Strength (G Force)			
	80°C x 1 hr.		20°C x 1 hr.	
Protein Concentration	15%	20%	15%	20%
Soya Isolate	382	3,012	167	832
Caseinate I	305	856	76	244
Caseinate II	262	548	42	221
Caseinate III	40	NT	27	NT
TMP	66	594	7	245
WPC	459	NT	-	-

NT: Sample not tested

Table 3 - Cooking Losses of Pre-formed Emulsions Manufactured with Different Protein Isolates

	Frying		Pasteurisation		Sterilisation	
	Cooking Losses (%)					
	Water	Fat	Water	Fat	Water	Fat
Soya Isolate	11.7	1.93	0	0.05	0	0.12
Caseinate I	41.4	EC	0	0.19	0.12	0.23
Caseinate II	29.9	EC	0.12	0.19	0.12	0.08
Caseinate III	42.1	EC	3.38	0.13	24.6	1.4
Caseinate I 'warm'	32.9	EC	0.18	0.11	0.41	0.06
TMP	38.7	EC	0.25	0.06	9.05	3.03
WPC	27.5	EC	0	0.89	0.07	0.59
Gluten	23.6	14.67	13.6	2.41	12.38	7.28

EC: Emulsion Collapse

Table 4 - The Effect of Chopping Times on Fat and Moisture Losses

	Fat Losses (%)		
Chopping Times (min)	1.5	2.5	4.5
Soya Isolate	2.1	1.9	1.7
Gluten	10.3	13.6	20.2

	Moisture Losses (%)	
	Chopped for 1.5 min	Chopped for 4.5 min
Soya Isolate	11.8	11.1
Caseinate I	43.6	38.6
Caseinate II	36.2	24.3
Caseinate III	44.8	40.6
Caseinate I 'warm'	33.7	27.8
TMP	38.5	37.7
WPC	28.1	25.9
Gluten	26.2	22.2

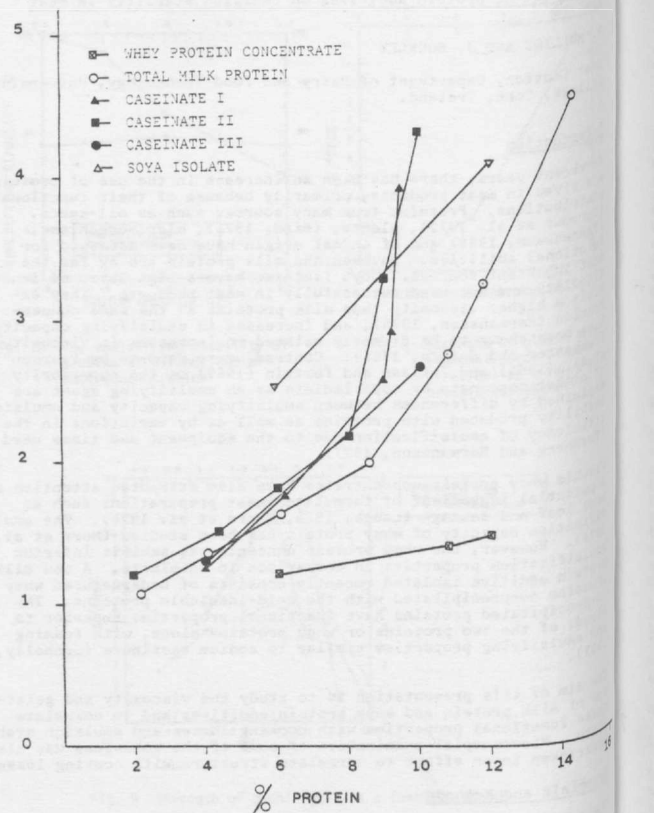

FIG. 1. VISCOSITY AS A FUNCTION OF PROTEIN CONCENTRATION

Table 5 - Caseinate II Type Emulsions with Fresh or Frozen Pork Fatty Tissue

	Fresh Fatty Tissue			Frozen Fatty Tissue		
Chopping Times (mins)	1.5	2.5	4.5	1.5	2.5	4.5
	Moisture Losses (%)					
Frying	36.2	29.3	24.3	45.7	41.2	38.1
Pasteurisation	0.18	0.19	0	0.77	0.94	0.9
Sterilisation	0.19	0.16	0	0.77	0.97	1.15

Table 6 - Emulsion Hardness and Cuttability

	Hardness (g Force)			Cuttability (g Force)		
Chopping Times (mins)	1.5	2.5	4.5	1.5	2.5	4.5
Soya Isolate	138	170	203	148	200	235
Caseinate I	179	229	229	95	106	138
Caseinate II	122	195	237	128	147	187
Caseinate III	13	17	21	NT	NT	NT
Caseinate I 'warm'	197	220	260	227	253	312
TMP	18	19	24	NT	NT	NT
WPC	21	18	16	NT	NT	NT
Gluten	57	47	46.5	NT	NT	NT

NT: Not tested due to Emulsion Softness

Table 7 - Emulsion Colour

Chopping Times (min)	1.5		2.5		4.5	
Colour Units	L	b	L	b	L	b
Soya Isolate	80.5	10.6	86.0	15.3	84.0	9.3
Caseinate I 'warm'	86.1	7.3	88.9	5.9	91.7	5.3
Caseinate III	87.2	6.6	87.7	6.5	92.5	5.8
TMP	85.1	9.7	86.1	9.1	87.9	8.9
WPC	77.1	8.8	78.2	9.0	77.1	9.2
Gluten	68.4	10.0	74.8	10.3	63.6	9.3

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