PHYSICO-CHEMICAL CHANGES DURING STORAGE OF PREBLENDED BEEF

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INTRODUCTION

Preblending of hot boned meat for sausage manufacturing results in a product of excellent binding and emulsifying properties (Hamm, 1973). However, the hot processing of meat is quite involved and, therefore, attention should also be directed to the possible beneficial effect of improving conditions by preblending of post-rigor meat. This is also a common practice currently being used in the U.S. meat industry (Shannon, 1975). Factors affecting the ability of meat to form good quality emulsion type sausages include emulsifying capacity, viscosity and water holding capacity. All of these factors are related to protein solubility and pH.

Measurement of emulsifying capacity was introduced into sausage technology by Swift et al. (1961) and since then, this method has been extensively used in this field. Borton et al. (1968) concluded that chopping beef cheeks with salt and water, 18 hours prior to laboratory examination increased the emulsifying capacity per unit of protein. Acton and Saffle (1969) showed that preblended post-rigor frozen meat emulsified 30% more fat in frankfurters than either fresh post-rigor or frozen post-rigor beef.

Hamm (1973) first stated that frankfurters were not emulsions in the true sense, and that fat particles were mainly mechanically fixed within a meat proteins matrix. Van den Oord and Wisser (1973) stated also that fat particles are not reduced enough in sausages to form a true emulsion system, and so, lipids are dispersed rather than emulsified in the protein matrix. This view of sausages agrees with the results of Meyer et al. (1964) who found that the inclusion of food emulsifiers did not enhance the performance of meat emulsions. Since fat particles are retained mainly due to the rheological properties of the dispersing phase, viscosity can be considered a useful index for evaluating meat since it is one of the most important single measurements of fluid foods including proteins (Kinsella, 1976). According to Briskey (1970) and Hermansson (1973) viscosity in food systems is related to protein hydration and both are directly influenced by pH, ionic strength, temperature and protein concentration. Hamm (1975) presented a comprehensive review of the rheological properties of meat homogenates; however, there are no references to viscosity changes in the meat homogenates due to preblending.

Closely related to viscosity, protein hydration, as measured by water holding capacity, is considered one of the principal factors responsible for the stability of a protein matrix (Schut, 1976). In emulsion type sausages, the most important factor influencing water holding capacity is the inclusion of salt. It is well known that adding sodium chloride to meat, at its normal pH, increases water holding capacity (Wierbicki et al., 1957) of the tissue.

All previously discussed properties depend on proteins. Swift et al. (1961) and Trautman (1964) indicated that the primary emulsifying agents in meat were the salt soluble proteins and Hegarty et al. (1963) showed that water soluble proteins and salt soluble proteins are both responsible for some of the emulsification properties. It has also been pointed out that there are differences in emulsifying capacity between the different salt soluble protein fractions (Tsai et al., 1972).

The purpose of this paper was to evaluate the influence of time and temperature conditions on physico-chemical properties of beef preblends prepared with two levels of added salt.

EXPERIMENTAL

Lean beef trimmings (5-10% fat) were finely ground twice through a 1/8" (3.2 mm) plate and after mixing to obtain a uniform batch, was subdivided to form two separate lots. To each of these lots, 20% water, 75 ppm of nitrite and either 3% or 6% salt, was added. After mixing the ingredients, the 2 lots were also subdivided into 10 samples. One sample from each salt level was analyzed immediately after preparation and the remaining samples were stored at -10°C, or 0°C or 15°C. The samples were analyzed once a day from each storage temperature for the following three days. The procedure was repeated four times.

Emulsifying capacity was evaluated using a slight variation of the method of Swift et al. (1961). A slurry was prepared by mixing for 2 minutes, 10 g of sample and 100 ml of 1 M NaCl (for 3% salt added samples) or 96 ml of 1 M NaCl and 4 ml of water (for 6% salt added samples). Aliquots of 10 g of the resulting slurry, corrected for salt content, were used to evaluate the emulsifying capacity using an omnimixer and refined soy oil. The breaking point was determined by visual appearance.

The consistometer described by Gould (1974) to measure tomato juice viscosity was used to evaluate the viscosity of the preblended slurries prepared with 75 g of beef preblend and 300 ml of 3% salt solution (for 3% added salt samples) or 240 ml of 3% salt solution and 60 ml of water (for 6% salt added samples). A slurry was prepared by using an omnimixer and blending for 1 minute, letting stand for five minutes and again blending for 1 minute. These slurries were filtered through a double layer of cheesecloth. The resulting filtrate was allowed to flow between the two marks in the GOSUC consistometer and the time in seconds needed to flow were the viscosity values.

Water holding capacity was determined by the method of Wierbicki and Deatherage (1958).

The pH values were evaluated using a Beckman Expandomatic SS-2 pH meter.

The amount of salt soluble proteins was determined on the same slurries used for viscosity evaluation after centrifuging at 4500 rpm for 10 minutes. Using the clear extracts, the protein content was evaluated by the biuret method of Gornall et al. (1949).

Data were submitted to overall analysis of variance using the Least Square and Maximum Likelihood General Purpose program of Harvey (1968). Mean separation was accomplished using the Duncan's New Multiple Range Test (Duncan, 1955).

RESULTS AND DISCUSSION

As shown in Table 1, the overall analysis of variance for emulsifying capacity values expressed on a "per gram of tissue" basis (EC) showed a significant linear effect for the amount of salt added. The preblends with 6% added salt had an overall least square mean (238.7) lower than the beef preblends with 3% added salt (LSM = 254.7). This result seemed to indicate that previous exposure of meat proteins to a higher salt concentration would reduce their ability to act as emulsifying agents, when tested under the same conditions, as done in this study. However, this apparent effect was cancelled simply by transforming the emulsifying capacity values into a "per 100 mg of total protein" basis (ECC). In this case the effect of added salt was not significant. Therefore, the significant reduction noted in EC when salt was increased in the preblends from 3 to 6% is mainly a reflection of the different protein content, due to the diluting effect of the added salt.

Table 1 - Degree of significance of the F values in the overall analysis of variance

Main effect	EC	ECC	VIS	WHC	pH	SSP
Salt	.0157	.1606	.5473	.0001	.6878	.1001
Linear temperature	.0623	.0673	.5923	.6361	.1255	.3298
Linear day	.7596	.7531	.3939	.1660	.0012	.0037
Quadratic day	.0084	.0084	.0094	.0000	.0029	.0599
Cubic day	.1569	.1590	.0130	.0124	.0258	.0000
Salt X temp	.1873	.1960	.0057	.4812	.7937	.1565
Salt X day	.7745	.7717	.7900	.4646	.7336	.0457
Temp. X day	.5280	.5068	.9944	.5058	.9628	.4080
Salt X temp. X day	.9706	.9731	.0799	.5830	.4681	.0949
	.5323	.7175	.7337	.0885	.5895	.0051

EC = Emulsifying capacity as ml of oil/g of sample.
ECC = Emulsifying capacity as ml of oil/100 mg of total protein.
VIS = Viscosity values.
WHC = Water holding capacity.
SSP = Salt soluble proteins.
Temp. = Temperature conditions.
Day = Length of storage.

The temperature of storage of the preblends did not influence significantly the emulsifying capacity values. Length of storage had a highly significant effect on emulsifying capacity. Table 2 presents the least square means of the emulsifying capacity of the 3% and 6% added salt preblends during storage. Emulsifying capacity of 3% added salt preblends decreased during storage, although this change was not large enough to be significant. However, in the 6% added salt preblends there was a significant ($P<0.05$) decrease in emulsifying capacity during storage. These results disagree with the report of Borton et al. (1968), who claimed from their results that preblending enhanced the emulsifying capacity of neck meat. They compared the emulsifying capacity of beef cheek blends containing 18% protein with beef cheek preblends where protein content was diluted to 10%. The dilution of the protein content should account for the increase in emulsifying capacity observed, as it is known that dilution increases the amount of oil emulsified per unit of protein (Hegarty et al., 1963; Trautman, 1964; Ivey et al., 1970). This effect relates to the differences in interfacial films being produced by different concentrations of protein (Grahan and Phillips, 1976). Acton and Saffle (1969) also showed that preblending increased the emulsifying capacity of post-rigor frozen meat. The differences which were apparent were due mainly to differences in protein solubility. After calculating the original data of these workers on the basis of ml of oil per 100 mg of total protein, the differences in emulsifying capacity were not apparent.

The viscosity of the extracts prepared from preblended beef was not affected significantly by the amount of added salt or the temperature of storage. However, viscosity values were significantly related to time of storage. There was a significant increase in viscosity after 1 day of storage, followed by a stable situation without any significant change during the second or the third day of storage (see Table 3). This pattern relates to changes which occurred in pH and protein solubility in the protein solutions (Hermansson, 1975; Hamm, 1975).

Table 2 - Least square means (LSM) of emulsifying capacity of beef preblends during storage

Days of storage	EC		ECC	
	3% salt	6% salt	3% salt	6% salt
	LSM	LSM	LSM	LSM
1	266.0[a]	261.2[a]	158.6[a]	160.2[a]
2	261.4[a]	242.2[a,b]	155.9[a]	148.3[a,b]
3	245.4[a]	219.3[b]	146.4[a]	134.3[b]
4	250.9[a]	232.1[b]	149.6[a]	142.2[b]

EC = Emulsifying capacity as "ml of oil per g of sample". Standard error is 9.2.
ECC = Emulsifying capacity as "ml of oil per 100 mg of protein". Standard error is 5.6.
a,b Means in the same column with same suprascript are not significantly different ($P>0.05$).

Table 3 - Least square means (LSM) of viscosity measurements (seconds) during storage of preblends

Day	LSM
1	41.7[a]
2	49.2[b]
3	46.0[b]
4	47.5[b]

a,b Means with the same suprascript are not significantly different ($P>0.05$), standard error is 1.2.

The water holding capacity of the preblends showed a significant effect due to the amount of added salt and the length of storage (Table 1). Temperature of storage did not cause a significant effect. In samples, initially the water holding capacity values of the 6% added salt preblends were significantly higher than those for the 3% added salt product. Water holding capacity is reported to increase with increased amount of added salt until the ionic strength of sodium chloride reaches 0.8-1.0 (Lawrie, 1974). During storage of preblends there was a significant increase in water holding capacity during the first day and then the values were stabilized (Table 4). This pattern relates closely to the one observed with viscosity values and can be attributed to the same basic factors.

The pH values were not affected by the amount of added salt. However, there was a significant effect of temperature and length of storage on pH values (Table 1). Table 5 shows the least square means and standard

errors of pH values in the preblends stored at the three different temperatures. Samples stored at 15°C had a higher pH than samples stored at lower temperatures. Samples stored at low temperatures (0°C or -10°C) did not differ significantly in pH values. The higher pH can be related to microbial development in the preblends as previously reported by Ockerman and Leon Crespo 1981. As shown in Table 6, the pH values of the preblends increased significantly ($P<0.05$) during the first day of storage and then did not change significantly thereafter.

Table 4 - Least squares means (LSM) of water holding capacity (percent bound water) measurements in preblended lean beef

Day	3% Salt LSM	6% Salt LSM
1	76.4[a]	85.2[a]
2	83.1[b]	90.2[b]
3	88.9[b]	93.3[b]
4	88.1[b]	91.4[b]

[a,b] Means with the same suprascript in the same column are not significantly different ($P>0.05$), standard error is 2.0.

Table 5 - Least squares means (LSM) of pH values in beef preblends stored at different temperature conditions

Storage temperature	LSM
-10°C	5.59[b]
0°C	5.57[b]
15°C	5.62[a]

[a,b] Means with the same suprascript are not significantly different ($P>0.05$), standard error is 0.01.

Table 6 - Least squares means (LSM) of pH values in beef preblends during storage

Days of storage	LSM
1	5.56
2	5.61
3	5.61
4	

[a,b] Means with the same suprascript are not significantly different ($P>0.05$), standard error is 0.01.

The amount of salt soluble proteins in the preblends presented a very complex pattern as revealed by the significance of the three ways interaction in the overall analysis of variance (Table 1). The least square means of the salt soluble proteins for the preblends during storage are presented in Table 7. There were significant alterations in the amount of salt soluble proteins in product stored at 15°C for the 3% salt added preblends and resulted in 4 days of storage having the highest LSM. However, in 0°C storage there was a significant decrease in salt soluble proteins after one day in the 3% salt added preblends. In the 6% salt added preblends there were no significant changes during storage.

Table 8 includes the values of the coefficients of correlation between the previously related factors. There was a significant relationship between pH values and viscosity and between pH values and salt soluble proteins. Viscosity, as previously discussed, depends on both pH values and the amount of salt soluble proteins. However, the relationship between viscosity and salt soluble proteins was not significant. Also the lack of a significant correlation between water holding capacity and viscosity, and between water holding capacity and pH value is surprising. The dependence of water holding capacity on pH value is well established.

Table 7 - Least squares means (LSM) of total soluble protein values (% of total protein) of beef preblends during storage

Storage temperature	3% Salt added			6% Salt added		
	-10°C	0°C	15°C	-10°C	0°C	15°C
Day	LSM	LSM	LSM	LSM	LSM	LSM
1	37.7[a]	37.7[a]	37.7[ab]	35.3[a]	35.3[a]	35.3[a]
2	32.4[a]	30.2[b]	32.7[a]	33.5[a]	31.6[a]	31.4[a]
3	32.2[a]	29.9[b]	36.7[ab]	32.6[a]	32.1[a]	32.8[a]
4	32.6[a]	32.1[b]	41.4[b]	32.1[a]	32.7[a]	35.6[a]

[a,b] Means with the same suprascript in the same column are not significantly different ($P>0.05$).

Table 8 - Correlations (adjusted for treatments) between the evaluated characteristics in beef preblends

	Viscosity	% Salt soluble proteins	Water holding capacity	Emulsifying capacity
pH	-.2958**	.2260*	.0778	-.0338
Viscosity	-	-.0718	-.0627	.1348
% Salt soluble proteins	-	-	.1649	-.0797
Water holding capacity	-	-	-	-.5453**

* Significant at 0.05 level.
** Significant at 0.01 level.

However, for post-rigor beef in the narrow range of pH of normal meat, no correlation between pH and water holding capacity is found (Lawrie, 1974). Surprising also was the correlation found between water holding capacity and emulsifying capacity. This coefficient of correlation was negative and highly significant. This was unexpected as water holding capacity relates to better quality in emulsion type sausages (Hamm, 1975) and the emulsifying capacity measurement was developed to evaluate the ability of proteins to emulsify fat in a meat emulsions (Swift et al., 1961). This significant negative correlation, however, agrees with the general pattern of changes observed in these two characteristics as influenced by temperature and length of storage, as already discussed. It is necessary to conclude that when the same type of meat is used, factors increasing the water holding capacity also produce lower emulsifying capacity. This fact has not been reported previously in the literature, but a hypothesis can be formulated that would explain these reactions. Conditions leading to a higher value for water holding capacity involve an opening of the structures of the proteins in meat, and a higher amount of water molecules interacting with the proteins. There is consequently a lower interaction between adjacent protein molecules when the water holding capacity is higher. The emulsifying capacity measures basically the elasticity of the protein films established around the surface of the fat globules, as pointed out by Schut (1976). The "breaking point" in the measurements by the method of Swift et al. (1961) is mainly an index of the failure of the proteins to maintain the elasticity and continuity of these films. It seems reasonable to suppose that conditions affecting the elasticity of these protein films will affect the emulsifying capacity values. When protein structures are "open", their interaction to form films is decreased. Therefore, when water holding capacity increases (opening of the structures), the emulsifying capacity will decrease (less resistant protein films are formed).

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