PHOSPHATES AND ANTIOXIDANTS AS CRYOPROTECTANTS IN MEAT BATTERS

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SUMMARY: The gelation and rheological properties of beef batters frozen with sodium chloride (1.5%), tripolyphosphate (TPP, 0.5%), sodium-acid-pyrophosphate (SAPP, 0.5%) and an anti-oxidant mix (BHA + BHT, 200 ppm) were studied. Leg beef meat (12 days post-mortem) was chopped in a non-vacuum bowl cutter for 1.5 min, and stuffed (500g) into moisture proof casings (6.2 cm dia.). The packages were frozen by direct air blast freezing, and kept at -18° for six months. Rheological parameters were determined on a Haake - rotary rheometer (model RV3), and modulus of rigidity (G) was recorded during thermal processing by using a thermal scanning rigidity monitor. There was no significant difference in K_0 (Casson flow limit) and K_1 (Casson apparent viscosity) values for meat with and without SAPP, however, K_0 decreased and K_1 increased when 0.5% TPP was added. After six months storage, only the anti-oxidant treatment maintained rheological properties. Maximum G increased when TPP was added, and unaffected by the addition of SAPP. After storing the meat for 6 months, no charge was noted in the meat without anti-oxidant. Thus, NaCl, TPP and SAPP decreased toughness of the cooked meat batter frozen by blast air and stored for 6 months.

INTRODUCTION: Most physical and chemical changes occuring in foods during freezing are caused directly or indirectly by water to ice transformation. Meat freezping usually results in an increased exudate released during thawing. Knowledge of the rheological behavior of meat batter is essential for the design of process conditions. However, few results have been reported on the effect of freezing rates on rheological properties of meat. The development of an acceptable texture in a meat system involves the coagulation of various proteins to form an elastic gel which is responsible for the unique characteristics of each product. Continuous rigidity scanning has been shown to be a sensitive method for detecting these sol to gel transformations and to assist in understanding the physical properties of the protein involved (Hamann, 1988). Thus, the objective of this study was to determine the effects of frozen storage with phosphates and anti-oxidants on the rheological and gelation properties of beef batters.

MATERIALS AND METHODS: Leg beef meat (12 d postmortem) was obtained from a local processing plant. The meat was trimmed of all visible fat and connective tissue and then chopped in a non-vacuum bowl cutter (model 84142, Hobart, Troy, OH) to obtain an homogeneous mass. Salt (1.5% NaCl) or tripolyphosphate (0.5%, TPP) or sodium-acid-pyrophosphate (0.5%, SAPP) or an antioxidant mix (BHA + BHT, 200 ppm) was added to the treatments before chopping. Proximate analysis of the meat (AOAC, 1980) was 74.05% moisture, 21.15% protein, 3.55% fat and 1.05% ash. The meat was stuffed (500g portions) into moisture proof casings (6.2 cm dia.) to ensure uniform size packaging for freezing. The package was frozen by direct air blast freezing. This method required 270 min to decrease the product (6.2 cm dia.) centre temperature from 2 to -6^{o} at -17^{o} ambient temperature. The sample temperatures were recorded with thermocouples inserted in their geometrical centre. After freezing, all the meats were kept frozen at -18^{o} for six months and then thawed at 3°C for 16h. Non-frozen (fresh) meat was used as a control treatment. The experiment was replicated twice.

Rheology and Water Holding Capacity: NaCl was added to the treatments without NaCl to extract some of the functional salt soluble proteins. The rheological parameters were determined in duplicate using a Haake type rotary rheometer (model RV3, Haake, Berlin, West Germany) and the SV-II measuring system, at a temperature of 5°C. The viscous drag of a rotating body, immersed in the batter, was converted to shear rate (s^{-1}) by multiplying it by a factor of 0.89 (provided by the manufacturer). Similarly scale reading were converted to shear stress (Pa) by multiplying the values obtained by a factor of 34.94.

Modulus of Rigidity: Continuous evaluation of the modulus of rigidity (G) during thermal scanning rigidy monitor (TSRM) based on the model described by Barbut and Mittal (1988). The TSRM consisted of a cylindrical jacketed chamber with a hollow cylinder held in the centre by upper and lower removable guides. The rate of heating was automatically controlled at 0.5°C/min, from 20 to 75°C, by a Haake PG20 controller connected to a heating coil immersed in the water bath. The TSRM was mounted on an Instron Universal Testing machine (model 4204) and at 2 minute intervals a cyclic force (from the upward-downward cyclic motion of the crosshead at 0.5 mm/min) was applied to the sample producing a small variable cyclic deformation. The shear modulus or modulus of rigidity was calculated as the ratio fo maximum shear stress to the maximum shear strain (Barbut and Mittal, 1988).

Statistical analyses were performed using the Statistical Analysis System (SAS, 1982). The General Linear Model for regression analyses, ANOVA procedure for analysis of variance and Duncan's multiple range test for ranking were used.

RESULTS AND DISCUSSION:

Rheology: The relationship between shear rate and shear stress for different treatment stored for a short period (1 d at -20°C) and long period (6 months) showed nonlinearity, and resembled the Bingham pseudoplastic behavior. The rheological parameters of the nonfrozen meat including the different treatments were determined by using the Casson equation (Table 1). The K_o varied from 29.72 to 44.35 $\sqrt{Pa}$ and K_1 from 0.71 to 5.99 $\sqrt{Pa.s}$ for all treatments. In

Table 1: **Casson equation[1] constants for the rheology of beef batters mixed with salts or antioxidants prior to freezing and after 6 months storage at -20°C.**

Non frozen					Frozen for 6 months				
K_o		K_1			K_o		K_1		
Estimate	SEE	Estimate	SEE	MSEE	Estimate	SEE	Estimate	SEE	MSEE
1. No salt added[2]									
41.90b	0.85	3.74b	0.36	4.01	43.53a	1.30	2.34b	0.39	9.32
2. Meat with 1.5% NaCl									
41.90b	0.85	3.74b	0.36	4.01	44.35a	0.69	2.16b	0.29	2.63
3. Meat with 0.5% TPP									
29.72c	0.50	5.99a	0.21	1.37	31.26c	0.38	4.42b	0.16	0.81
4. Meat with 0.5% SAPP									
34.45b	0.38	3.78b	0.16	0.80	40.18b	0.42	0.71c	0.18	0.96
5. Meat with 200 ppm BHA + BHT									
41.90b	0.85	3.74b	0.36	4.01	42.70b	0.80	1.83b	0.34	3.56

(1) $\sqrt{\tau} = K_o + K_1\sqrt{\gamma}$, K_o is Casson flow limit, $\sqrt{Pa}$; and K_1 is Casson apparent Viscosity, $\sqrt{Pa}.s$

(2) No salt added prior to freezing (control)

a,b,c = means of a parameter with the same letter are not significantly different at 95% level.

Results are the averages of both trials. SEE = standard error of estimate, MSEE = mean sum of squares of error; and P > |T| = 0.0001 for all estimates.

a preliminary experiment it has been established that adding the 1.5% NaCl prior or after freezing and the addition of 200 ppm of the antioxidants did not affect the rheological properties of the meat. There was no significant difference in K_o and K_1 values for meat with and without SAPP; however, K_o decreased and K_1 increased when 0.5% TPP was added.

After six months storage, only the antioxidant treatment maintained meat rheological properties similar to the fresh meat. Without any antioxidant or with 1.5% NaCl, meat rheological parameter K_o increased significantly, however, K_1 was unaffected. With the addition 0.5% TPP or SAPP, K_1 decreased but K_o was unaffected.

The apparent viscosity was unaffected by shear rates greater than 3 s^{-1} for all treatments. Only at lower shear rates, apparent viscoity was affected except for fresh meat and meat frozen with BHA + BHT stored for 6 months. This indicates the effectiveness of BHA + BHT to maintain rheological qualities during storage and prevent some of the damages assocaited with long term freezing of meat.

Gelation: Plots of modulus of rigidity (G) versus internal temperature of the meat during cooking are shown in Figures 1 and 2. Table 2 shows the minimum and maximum values of G for the

Table 2: **Minimum and maximum modulus of rigidity (G,kPa values for various salts and antioxidant treatments.**

Treatment	Non frozen		Frozen for 6 months	
	Minimum G,kPa	Maximum G,kPa	Minimum G,kPa	Maximum G,kPa
No salt added[1]	5.28^a at 36°C	20.58^b at 68°C	5.30^a at 35°C	22.46^b at 67°C
1.5% NaCl	5.28^a at 36°C	20.58^b at 68°C	4.45^b at 36°C	14.89^c at 64°C
0.5% TPP	3.54^c at 23.5°C	32.48^a at 73°C	4.09^b at 26.5°C	24.40^b at 71°C
0.5% SAPP	4.79^b at 23°C	22.69^b at 67°C	3.65^c at 26°C	11.28^c at 66.5°C
200 ppm BHA+BHT	5.28^a at 36°C	20.58^b at 68°C	4.32^b at 24°C	16.97^b at 65.5°C

(1) No salt added prior to freezing (control)
a,b,c=means of a parameter with the same letter are not significantly different at 95% level.

different treatments. Minimum and Maximum G were unaffected when NaCl or BHA + BHT were added to the meat. Minimum G was decreased when TPP or SAPP were added, the decrease was more pronounced when TPP was added; while maximum G increased when TPP was added, and unaffected by the addition of SAPP. Thus, TPP significatnly increased the G in the cooked product. After storing the meat for 6 months, no change was noted in the meat without antioxidant. While the NaCl and SAPP treatments decreased both the minimum and maximum G values.

TPP addition increased the minimum G and decreased the peak G value, while BHA + BHT decreased minimum G and did not change the peak value. Thus, NaCl and SAPP were responsible for decreasing the toughness of the cooked meat batter which was frozen by blast air and stored for 6 months.

During heating, all the batters did not show any gel structure formation up to 40°C. This was followed by a modest increase in the G value up to 55-58°C, and then followed by a rapid increase in G up to the peak values occuring at 67 to 73°C. A decrease in G was observed above these temperatures, except for the two phosphate treatments which were stored for one day, and the TPP treatment stored for 6 months. The decrease in G observed above 65°C in some of the treatments was probably due to the slippage of the batter in the TSRM. In the gelation curves, three transition temperatures were observed: the first at 42-43°, the second at 57-58°C and third at 64-73°C.

REFERENCE: - AOAC (1980). Official methods of analysis. Assoc. of Analytical Chemists, Washington, D.C.
- Barbut, S.B. and Mittal, G.S. (1988). J. Food Sci. 54:1296.
- Hamann, D.D. (1988). Food Technol. 42(6):66.
- SAS (1982). SAS User's guide. Statistical Research Institute, Cary N.C.

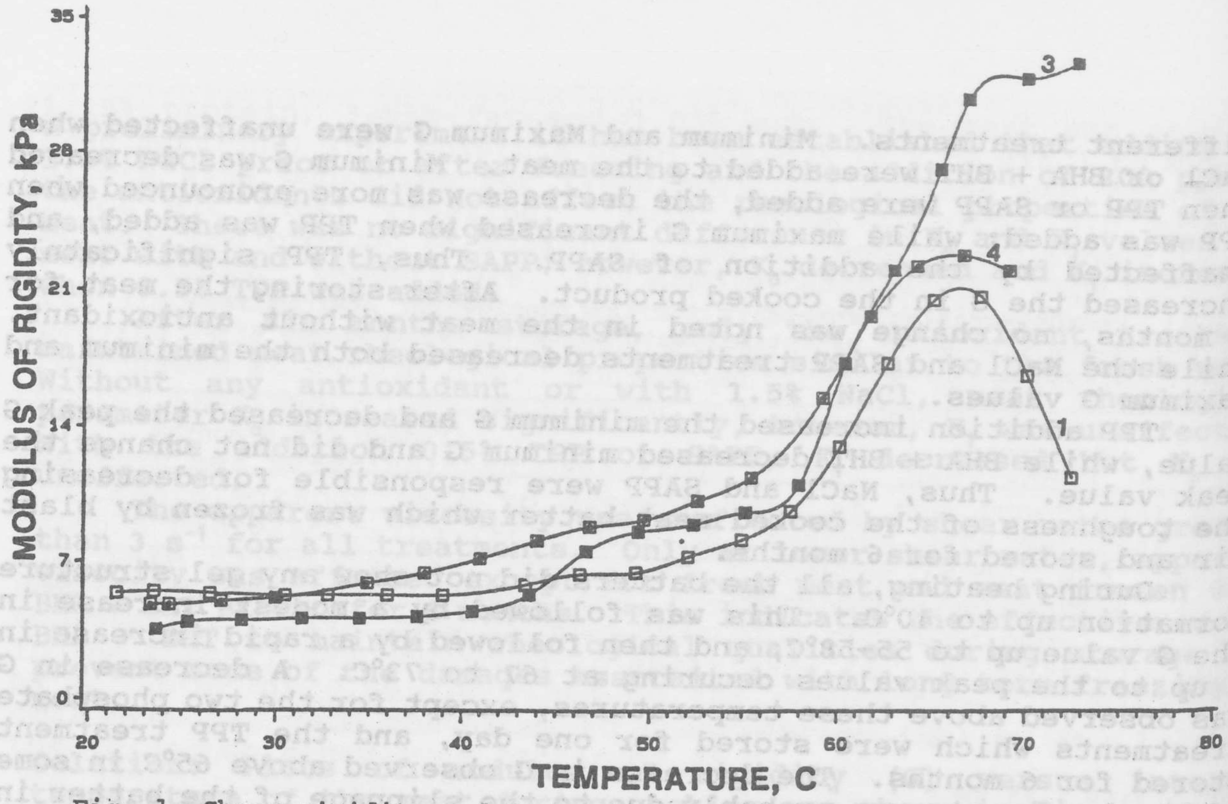

Fig. 1: Shear rigidity modulus profiles of batters, frozen by air blast freezing, during cooking. "1" = unsalted meat or with 1.5% salt or with 200 ppm BHA + BHT; "3" = 0.5% TPP; and "4" = 0.5% SAPP. These were measured after 1 day storage.

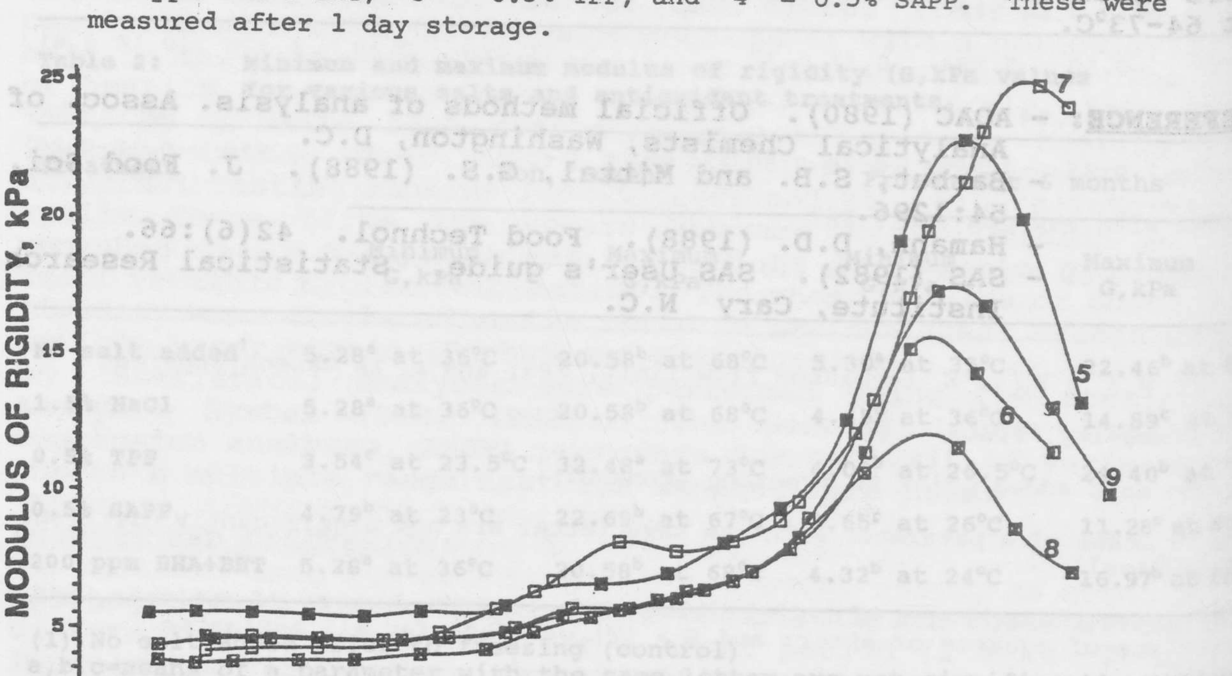

Fig. 2: Shear rigidity modulus profiles of beef batters, frozen by air blast freezing, during cooking. "5" = unsalted meat; "6" = 1.5% NaCl; "7" = 0.5% TPP; "8" = 0.5% SAPP; and "9" = 200 ppm BHA + BHT. These were measured after 6 months storage.