EFFECTS OF VARIOUS FILLERS ON THE SMOKEHOUSE COOKING KINETICS OF MEAT BATTERS

L.R. Correia[1], G.S. Mittal[1] and W.R. Usborne[2], School of Engineering, University of Guelph, Guelph, Ontario, Canada, N1G 2W1.

SUMMARY

The cooking kinetics of meat batters containing various fillers was determined by monitoring changes in selected rheological and functional properties during smokehouse cooking. The fillers used were butter-milk powder, corn starch, modified corn starch, modified wheat flour, soy-protein concentrate, whey protein concentrate and micro-crystalline cellulose. The cooking process was modelled using reaction kinetics and Eyring's absolute reaction rate theory. For all properties, a zero-order rate was obtained. Enthalpy and entropy changes of activation were calculated for various properties and fillers.

INTRODUCTION

A meat batter is a two phase system with fat as a dispersed phase and water-meat-protein medium as continuous phase. The incorporation of non-meat ingredients (fillers) changes the micro-structure and other properties. There is a need to have objective methods of predicting desired finished product attributes based on the knowledge of raw material formulation and process conditions. This paper discusses the determination of meat batter cooking kinetic parameters for various properties and fillers.

If process conditions are kept constant, product attributes are dependent upon the composition and their interactions. Thus, the prediction of product attributes as a function of composition is desired.

Porteous and Quinn (1979) investigated whether the combination of meat and fillers acted synergistically to provide higher value of a property or antigonistically to provide a lower value than measurements on each alone would predict. Bawa (1983) concluded that the

Table 1 : Kinetic parameters for various properties changes of meat batter during smokehouse cooking.

Fillers	kinetic parameters*		kinetic parameters		kineticparameters	
	ΔS	ΔH	ΔS	ΔH	ΔS	ΔH
	E1		E2		T_2	
CON**	-199	37465	-132	59738	-316	1384
BMP	-178	44461	-132	59420	-311	1918
CS	-200	37691	-108	67814	-312	1957
MCC	-257	18811	-202	36559	-310	1931
MCS	-143	56290	-100	70249	-311	1704
MWF	-195	38991	-125	61878	-313	1713
SPC	-212	33353	-191	40079	-312	1559
WPC	-189	41086	-81	76622	-310	2014
	Hardness 1		Springiness		chewiness	
CON	-307	2258	-317	1417	-310	2211
BMP	-307	2277	-318	1260	-310	2284
CS	-223	30129	-427	-26430	-314	2068
MCC	-312	1928	-310	1960	-306	2309
MCS	-204	36125	-290	9300	-181	44359
MWF	-307	2203	-324	-370	-313	1784
SPC	-308	2168	-309	1857	-306	2329
WPC	-309	2185	-366	-8620	-316	1558

Fillers	kinetic parameters*		kinetic parameters		kineticparameters	
	ΔS	ΔH	ΔS	ΔH	ΔS	ΔH
	Gel-strength		Cook loss		WHC	
CON	-306	2370	-322	855	-329	-1723
BMP	-188	41400	-323	717	-322	-240
CS	-175	45330	-313	1860	-316	957
MCC	-310	2267	-328	-132	-300	6548
MCS	-310	2290	-331	-803	-282	11228
MWF	-160	50220	-325	586	-311	1863
SPC	-187	41710	-329	-318	-326	-1011
WPC	-170	47050	-317	1330	-313	1264
	pH		Lightness (L)		'a'	
CON	-375	-17725	-276	14882	-308	1936
BMP	-334	-2490	-286	10825	-268	15437
CS	-383	-21210	-279	11968	-250	20525
MCC	-360	-13858	-261	19637	-315	1345
MCS	-325	-1900	-300	5078	-273	14296
MWF	-396	-23117	-293	8423	-309	1880
SPC	-401	-26946	-276	14818	-310	1992
WPC	-438	-37518	-280	13933	-235	25495

*ΔS is in kJ/(kg mol.K); and ΔH in kJ/kg mol.

** CON= control, BMP= butter milk powder, CS= corn starch, MCS= modified corn starch, MCC= micro-crystalline cellulose, MWF= modified wheat flour, SPC= Soy-protein concentrate, and WPC= whey protein concentrate.

Table 2: Regression parameters of linear enthalpy - entropy relationship for properties changes of meat batters during smokehouse cooking

$(\Delta H = A.\Delta s + B)^*$.

Properties	A,K	B, MJ/kg mol.
E_1	327	102.8
E_2	332	103.5
Hardness 1	326	102.6
Hardness 2	324	102.1
Cohesiveness	354	113.8
Springiness	246	79.2
Gumminess	318	100.9
Chewiness	323	102.6
Gel-Strength	324	102.1
Cooking Loss	141	46.1
WHC	280	89.7
pH	325	104.2
L	366	115.4
a	314	99.5
b	244	77.9

* PR >F is ≥0.0001 except for b, which is 0.02

interaction between fillers and meat was significant for emulsion capacity and stability. Siripurapu et al. (1987) obtained creep data for a meat batter of different fat-protein ratio, cooked at various temperatures for varying holding times. Not much work has been published on kinetic modelling of meat batter containing different fillers during smokehouse cooking.

MATERIAL AND METHODS

For 8 treatments and 2 replications, the total number of experiments were 16. The process conditions were held constant. Uncooked meat batter composition was lean beef (59.5 or 49.1%), pork fat (20 or 15.2%), filler (0 or 8.6%), salt (1.66%), soluble spice mix (0.48%), nitrite mix (0.3%), and ice (18.1 or 28.8%). The first number in the brackets is for control (no filler) and second for treatments with fillers. The compositions of the fillers were: butter milk powder (44, 34, 5, 6), corn starch (90, 0, 10, 0), micro-crystalline cellulose (94, 0, 6, 0), modified corn starch (90, 0, 10, 0), modified wheat flour (47, 45, 8, 0), soy protein concentrate (26, 67, 6, 0.5), and whey protein concentrate (53, 35, 4.5, 5). These numbers represents carbohydrate, protein, moisture and fat contents in percentages, respectively.

Meat batter preparation: Lean beef and pork fat of known compositions were stored in a freezer. When required, these were thawed to about 66 h in a cooler at 2°C, and then ground through a 6.4 mm plate. The Cutmaster chopper (model SMK 40) was used for chopping. A vacuum tumbler (Lyco, model 40) was used to reduce the number of large air pockets in the batter. Th raw batter was then stuffed into 22 mm diameter cellulose casing using a hydraulic stuffer, then linked with a manual linker. Each link was about 150 mm. For thermal processing, a microprocessor controlled smokehouse was used. Vertical air flow pattern with 14 air changes per minute, 0.6°C/min change in dry bulb temperature, and 0.58°C/min in wet bulb temperature were employed. Samples of the frankfurters were drawn when the product central temperature reached 30, 40, 50, 60, 65 and 70°C. The temperature measuring system comprised of a portable computer, a data logger, and T-type thermocouples. The product samples were stored at 2°C until required for testing.

Properties measurement: A modified Saffle (1976) method was used to determine the emulsion stability,and computed by dividing the fat volume by the sample mass (ml/g). Stress relaxation (Bourne 1982) was performed on 20 mm diameter and 15 mm high samples on an Instron testing machine (model 1122). A cross head speed of 50 mm/min, chart speed of 20 mm/min, and 20% compression for 9 min were employed. The texture profile analysis (TPA) test (Bourne 1982) comprised of two cycles providing 75% compression in each cycle. The TPA parameters were computed from the output recorded at a chart speed of 200 mm/min. The gel strength was the maximum penetration force recorded when a cylindrical punch, 6.4 mm in diameter, penetrated the product sample by 40%.

The water holding capacity (WHC) was determined by dividing the water held by the sample after applying 63.5 kPa vacuum for 4h by the dry mass of the sample. Cooking losses were computed as the loss of water during cooking and were based on the wet mass of the samples.

The Spectrogard colour system (model 96) with Hunter lab colour scale was used to determine product colour. The Hunter lab scale parameters of 'L','a' and 'b' were determined. For pH measurement 10 g of the sample was mixed with 90 g of deionized distilled water. The press juice was measured by pressing 1 g of the sample between aluminum foils and filter papers at a force of 6.8 kN for 1min. The loss of sample mass divided by the original sample mass yielded press juice. The consumer cook test (CCT) was conducted by placing a known mass of about 6 to 8 frankfurters into a sauce pan containing 100 ml of boiling water. When boiling resumed, the pan was allowed to cool to 60°C at room temperature. Then the mass of the drained frankfurters was noted. The % loss or gain was computed based on the original frankfurters mass.

Kinetic modelling: The product temperature history was modelled by the following equation:

$$T = P + Q\,(t\text{-}t_i) + S.\sin(6.284(t\text{-}t_i)/t_p)$$

where T is product centre temperature, K; t is time, min; and rest are constants. To calculate the slope of the product-temperature history curve, small fluctuations were neglected; and slope was considered to be equal to

'θ'. The change in property values (P_r) were modelled by quadratic or exponential model

$$(P_r = B_1 T + B_2 T^2 \text{ or } P_r = \text{Exp}(B_1 + B_2 T)).$$

A reaction kinetic is generally modelled by

$$dc/dt = -kC^n \quad \text{or} \quad dx/dt = k(1-x)^n$$

where C is concentration, k is reaction rate constant, n is reaction order, and x is fraction reacted or degree of cooking defined as:

$$x = (P_r - P_{ri})/(P_{rm} - P_{ri})$$

Where subscript i denotes initial and m is for minimum or maximum value. Thus x varies from 0 to 1 during cooking. Taking $dx/dt = (dx/dT)(dT/dt)$; $dT/dt = Q$; $dx/dT = (dPr/dT)/(P_{rm} - P_{ri})$; and $k = KT/h \text{ Exp}(\Delta s/R - \Delta H/RT)$ i.e. Eyring's absolute reaction rate theory.

Thus final reaction kinetics can be written as:

$$dPr/dT = KT(P_{rm}-P_{ri})/(h.Q).\text{Exp}(Ds/R - DH/RT)(1-x)^n$$

where R is gas constant (8.314 kJ/(kg mol.K)), K is Boltzman's constant (1.38E-23 J/K), h is Planck's constant (6.625E-34 J.s), Δs is entropy change of activation (kJ/kg mol.) Thus Δs, ΔH and n were calculated for all the properties of meat batters. Statistical analysis system (SAS 1985) was used for this purpose, 'n' was found to be zero for all the properties changes.

RESULTS AND DISCUSSION

Stress relaxation parameters: A model containing two Maxwell units in parallel was used to predict the stress relaxation behaviour.

The modulus of elasticity (E) was represented by:

$$E(t) = E_1 \text{Exp}(-t/T_1) + E_2 \text{Exp}(-t/T_2)$$

Where E_1 and E_2 are the elastic modulii of the spring, and T_1 and T_2 are the relaxation times.

The values of E_1 and E_2 increased exponentially with product-temperature for all treatments. The kinetic parameters are given in Table 1. The lowest value of R^2 obtained was 0.9998. The regression parameters of a hypothetical linear enthalpy-entropy relationship for E_1 and E_2 are also shown in Table 2.

Textural profile analysis and gel strength: For most treatments, the quadratic model was used to fit the TPA parameters cooking-time relationship. The kinetic parameters for these properties changes are given in Table 1.

Hydration and other properties: Cooking loss decreased with increase in product-temperature for all treatments, and the quadratic model was found suitable. The pH also increased during cooking, and the quadratic model was used to fit the data. For all treatments, the lightness (L) decreased during cooking. The quadratic model was used to fit the data of 'L', 'a' and 'b'. The kinetic parameters are given in Table 1.

REFERENCES

Bawa, A.S. (1983). Functionality of fillers and extenders in meat emulsions. Ph.D. dissertation, Univ of Guelph, Guelph Canada.

Bourne, M.C. (1982). Food texture and viscosity: Concepts and measurements. Academic Press, New York.

Proteous,J.D. and Quinn, J.R. (1979). *Can. Inst. Food Sci. Technol. J.* **12**(4):203.

Saffle, R.L., Christian, J.A., Carpenter, J.A. and Zirkle, S.B. (1976). *Food Technol.* **21**:784.

SAS (1985). SAS User's guide: statistics. SAS Institute Inc., Cary, NC, USA.

Siripurapu, S.C.B., Mittal G.S. and Blaidsell, J.L. (1987). *J. Food Sci. Technol.* (LWT) **20**(2):68.