MEAT BATTER FILLER SELECTION BASED ON COOKING KINETICS PARAMETERS

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There is a need to predict consumer related characteristics of a cooked sausage based on its raw material composition. This can be achieved if kinetics of meat emulsion cooking as a function of composition is understood. A major concern in the manufacture of meat emulsion products has been to balance the quality and quantity of protein with processing functionality, nutritive value and cost. Therefore, in addition to protein from meat sources, a variety of fillers have been utilized in cooked comminuted meat products to reduce cook shrink and formulation costs, as well as to improve emulsifying capacity, emulsion stability, water binding potential, nutritive value and slicing characteristics (Mittal and Usborne, 1985).

This paper reports the selection criteria of fillers in meat emulsions based on cooking kinetics parameters and filler properties.

MATERIAL AND METHODS

Emulsion preparation

On the basis of source material, functional properties and potential usage, the following fillers were selected. The number in brackets represent carbohydrate, protein, moisture and fat content in percentages, respectively: butter milk powder (BMP) (44, 34, 5, 6), corn starch (CS) (90, 0, 10, 0), micro-crystalline cellulose (MCC) (94, 0, 6, 0), modified corn starch (MCS) (90, 0, 10, 0), modified wheat flour (MWF) (47, 45, 8, 0), soy-protein concentrate (SPC) (26, 67, 6, 0.5), and whey protein concentrate (WPC) (53, 35, 4.5, 5). Compositions were provided by the manufacturers. Raw meat emulsion composition was based on the targeted meat protein level of 9.55%, meat fat-protein ratio of 1.8 and moisture content of 61.8% in the cooked product. The soluble spice mix contained 97% salt and < 0.2% glycerine, and nitrite source contained 85%, salt 8.3% sodium erythorbate, 6.4% sodium nitrite, 2% sodium carbonate, and < 0.2% glycerine. Total salt content was 2.38% in the raw meat emulsion, whereas the soluble spice level was 0.014%, and sodium nitrite level was 190 ppm. For 8 treatments (7 fillers and 1 control without filler) and 2 replications, the total number of experiments were 16. The process conditions were held constant (Correia and Mittal 1988).

When the product centre temperature reached 30°C, the smokehouse door was opened and a rod, bearing 3 or 4 strings of frankfurters, was withdrawn. The procedure was repeated when the product temperature reached 40, 50, 60, 65 and 70°C. Showering was performed at the end to prepare fully cooked product. The samples enclosed in polyethylene bags were stored at 2±1°C until required for testing (Correia and Mittal, 1988; and Correia 1988).

Filler Properties

Various functional properties were determined for each filler using appropriate methods (Correia 1988). These included cold water absorption (CWAF) and hot water absorption (HWAF) in g water per g dry filler; cold water solubility (CWSF) and hot water solubility (HWSF) in g soluble solids per g total solids; gel strength (GSF) in N; and water holding capacity (WHCF) in g water per g dry filler.

Meat emulsion properties

Frankfurter samples of 20 mm in diameter and 15 mm in length were used for stress relaxation, gel strength and texture profile analysis (TPA) (Bourne, 1982). For stress relaxation, samples were subjected to 20% compressive strain for 9 min. Elastic moduii (E_1 and E_2) and relaxation times (τ_1 and τ_2) of the maxwell bodies 1 and 2 in parallel were calculated. The TPA test comprised of two compression cycles, each conducted at 75% compression. The TPA parameters of hardness (first and second bite) (H_1 and H_2), cohesiveness (COH), springiness (SPN), gumminess (GUM) and chewiness (CHW) were computed. The gel strength (GS) was the maximum penetration force recorded when a cylindrical punch, 6.4 mm in diameter, penetrated the sample by 40%. Other measured functional properties included emulsion stability (ES), water holding capacity (WHC) cooking loss (CLC), colour (L,a,b), pH, press juice (PJ) and consumer cook test (CCT).

Kinetic modelling of the cooking process was undertaken by considering the properties changes during cooking (Correia and Mittal 1988). The rate of reaction was found to be zero for all the properties changes. The entropy change of activation (ΔS) and enthalpy change of activation (ΔH) were computed.

RESULTS AND DISCUSSION

Kinetic parameters of meat emulsion properties changes during smokehouse cooking

Kinetic parameters (ΔH and Δ S) were computed for stress-relaxation, textural and functional meat emulsion properties changes during cooking. These are discussed in details elsewhere (Correia 1988; Correia et al. 1988, Correia and Mittal 1988).

Effects of showering on the meat emulsions

Table 1 summarizes the mean properties difference due to showering and a paired t-test results.

The decrease in cooking loss (CLC) by 3.8% due to showering suggested that some water penetrated through the semi-permeable casing and emulsion skin during this process. The showering influenced the following properties significantly

Table 1. Results of paired t-test performed on the difference between meat emulsion properties after and before showering.

	Difference*	Pr > |t|
E_1, kPa	-7.1	0.02
τ_1, min	1.04E-02	0.07
E_2, kPa	-8.8	0.01
τ_2, min	0.42	0.73
H_1, N	-12.5	0.002
H_2, N	-7.9	0.005
COH	-0.83E-02	0.69
SPN, cm	4.58E-02	0.208
GUM, N	-2.02	0.056
CHW, N.cm	-0.69	0.49
GS	-0.30	0.006
CLC	-3.8	0.0002
WHC	-0.58	0.375
pH	1.68E-02	0.009
L	0.78	0.003
a	-0.47	0.006
b	0.01	0.877

*Property after showering - property before showering; number of observations = 8.

(at 5% level): E_1, E_2, H_1, H_2, GS, pH, L and a. First five are related with the product hardness or rigidity, which were decreased due to showering. pH and colour lightness (L) increased and redness (a) decreased.

<u>Enthalpy Change of Activation (Δ H) and Filler Properties</u>

A relationship of Δ H with filler properties will render the kinetic approach more useful for product design purposes. Correlation coefficients between Δ H for meat emulsion properties changes during cooking, and filler properties were calculated. Relationships between Δs and filler properties were not investigated since Δ H was linearly related to Δ s for most meat emulsion properties. The relationships between Δ H and filler properties <u>displayed significant correlations at</u> the 10% level, and no increasing or decreasing trend: Δ H (E_1) versus CWAF, Δ H (H_1) versus pHF, Δ H (H_2) versus WHCF, Δ H (GUM) versus GSF, Δ H (CHW) versus WHCF, Δ H (CHW) versus GSF, Δ H (GS) versus GSF, Δ H (GS) versus WHCF, and Δ H (WHC) versus GSF. Equation 1 to 8 show suitable regression models of Δ H for meat emulsion properties changes as a function of the filler properties. The limitation of these models are the low degrees of freedom, but care was taken to include only those models which predicted the data effectively. The selection was made after plotting the observed data and predicted curves.

$$\Delta H (E^2) = 32880 + 36182/CWAF \quad (1)$$

$$\Delta H (H^1) = 2508 - 1412\ WHCF \quad (2)$$

$$\Delta H (GUM) = 3171 - 36159\ WHCF^2 \quad (3)$$

$$\Delta H (GS) = Exp\ (12.81 - 0.59\ HWAF) \quad (4)$$

$$\Delta H(CLC) = -685+Exp(9.022-1.004GSF) \quad (5)$$

$$\Delta H(WHC) = -2364 + 78518\ WHCF^2 \quad (6)$$

$$\Delta H(L) = 18825[1-Exp(-0.50CWAF)] \quad (7)$$

$$\Delta H(b) = 28537-8463\ pHF + 754\ pHF^2 \quad (8)$$

The aforementioned models will provide the properties up to 70° i.e. before showering the product. The desired properties of fully cooked product can be converted to the properties at 70°C using Table 1 <u>(Correia 1988). After integrating</u> the cooking kinetics equation between 30 and 70°C, the Δ H can be computed. After knowing Δ H, regression models will provide the necessary filler properties, which will help to select a particular filler or blend of fillers by matching the desired properties with filler(s) properties. To complete these calculations, raw meat emulsion properties are required, which can be estimated from the raw meat emulsion properties given by Correia (1988).

<u>Fully Cooked Meat Emulsion and Filler Properties</u>

Since many product quality parameters were not predicted by cooking kinetics, attempts were made to predict fully cooked product quality as a function of filler properties. The correlation coefficients between fully cooked meat emulsion and filler properties were computed.

The following relationships between fully cooked meat emulsion and filler properties displayed significant correlation at the 10% level, and no increasing or decreasing trend: E_2 versus GSF, τ_2 versus WHCF, COH versus HWAF, CLC versus CWSF, PJ versus CWSF, CCT versus pHF, pH versus CWSF, and L versus WHCF. Equations 9 to 15 show suitable regression models of fully cooked meat emulsion properties as a function of filler properties.

$$E^1\ (kPa) = 40.71-14.93\ HWSF^2 \quad (9)$$

$$H^1(N) = 83.46[1-exp(-2.71\ GSF)] \quad (10)$$

$$CLC(\%wb)=4.20-6.08HWSF+2.38HWSF^2 \quad (11)$$

$$PJ(\%) = Exp[3.18 + 0.69\ HWSF^2] \quad (12)$$

$$PJ(\%) = Exp\ (3.44 - 0.19\ GSF) \quad (13)$$

$$a = 6.23+43.48\ WHCF-44.12\ WHCF^2 \quad (14)$$

$$a = -232.5+85.22\ pHF-7.28\ pHF^2 \quad (15)$$

Filler Selection Criteria

Fully cooked meat emulsion properties are influenced by product composition and process conditions. In the present study, process conditions were held constant. Except for filler-type, the same product composition was used for all treatments. For desired fully cooked meat emulsion product decay modulus of elasticity (E^1), hardness, cooking loss, press juice and redness, the required filler property can be calculated using equations 9 to 15. It is evident that HWSF affects both E^1 and CLC, whereas GSF affects H^1 and PJ. Hence, there is a need to establish a composite function relating fully cooked meat emulsion properties to filler properties. For example, a collective optimization function for all the fully cooked meat emulsion properties E^1, H^1, CLC, PJ and a was derived by weighing all coefficients of these parameters models except CLC with +1, and CLC with -1, and then summing the terms to form the following function (OPT):

$$OPT = - 106.31 + 6.084\ HWSF - 17.31\ HWSF^2 + 43.48\ WHCF - 44.12\ WHCF^2 + 85.22\ pHF - 7.28\ pHF^2 - 83.46\ exp(-2.769\ GSF) + exp(3.182 + 0.6950\ HWSF^2) + exp(3.436 - 0.1874\ GSF)$$

The OPT function was then maximized using the optimization program of Mittal and Usborne (1986). The necessary filler properties required were GSF = 1.419 N, HWSF = 0.8700, WHCF = 0.4930 and pHF = 5.854. Thus, meat processors can determine the appropriate filler properties to satisfy any OPT function of interest.

Fillers are used in meat emulsion products to satisfy economic, nutritional and functional needs. There are opportunities to use fillers to decrease the fat and salt levels, and increase the usage of vegetable fibre. However, the success of using conventional or novel filler was depend on the ability to estimate fully cooked meat emulsion properties. These filler selection criteria can help in preliminary screening of novel fillers or a blend of fillers with known properties, obviating the need for costly and time consuming pilot-plant experiments. This provides the meat processing industry with more flexibility in filler selection for product design purposes.

CONCLUSIONS

Reaction kinetics and Eyring's absolute reaction rate theory were satisfactorily modelled the cooking kinetics of the meat emulsions based on properties changes. The value of the reaction order was zero. Showering significantly decreased meat emulsion elastic modulii, hardness, gel strength, cooking loss and redness, and increased pH and colour lightness. Regression models of ΔH as a function of filler properties were developed for E^2, H^1, GUM, GS, CLC, WHC, L and b; and models of fully cooked meat emulsion properties as a function of filler properties were also developed for E^1, H^1, CLC, PJ and a. Filler selection can be based on regression models relating ΔH for key meat emulsion property changes during cooking, or key fully cooked meat emulsion properties as a function of filler properties.

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