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Protein Functionality and Development of Bind Values

ROBERT A. LABUDDE and TYRE C. LANIER*

INTRODUCTION

Although sausage production is an ancient art dating to classical times, the preparation of modern fine-cut cooked products is a complex process. Increasingly, large-scale manufacturers throughout the world are providing mass-produced and economical sausages to their markets.

The complexity of the task and the reduction in safety margin have forced the use of computer formulation and modeling to maintain low costs without increasing processing failures. The tools used to accomplish this are a set of "bind" constants (functionality coefficients) for common meats used, together with a "least cost formulation" (linear programming) computer program to manipulate the model and minimize cost.

To a large extent, the widespread use of these tools is due to the efforts of one man: Robert L. Saffle, during his tenure at the University of Georgia. Although Saffle did not invent the methods he proselytized, he standardized their use, documented their workability and educated and encouraged the industry.

So successful was Saffle in his promulgation that meat processors throughout the world recognize the word "bind" and understand its basic meaning (i.e., capability of meat to bind the sausage together). Sometimes the value is referred to as the "bind constant," "bind value" or "bind index." The term "bind index" will be used here for definitiveness, and will be defined later.

Paradoxically, some of the most often asked questions from these meat processors are: What is the bind index? How is it measured? What does its value mean relative to the product made?

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In what follows, an attempt will be made to answer these questions. For illustration, Table 1 presents a compilation of all meats tested by Saffle and his coworkers (chiefly John A. Carpenter) at the University of Georgia over the years, together with their proximate analyses and average measured bind/color indices. Several adjustments have been made in the original data to correct clearly erroneous analysis values.

EARLY HISTORY

It was well recognized by the 1950's that certain kinds of meats bound the comminuted sausage more tightly together than other kinds of meats. Cuts of meat were classified into gross categories, such as good binders (bull meat, cow meat), poor binders (hearts, cheeks, fat meat) and fillers (lips, tripe, stomachs). Sufficient lean meat of good "bind" was known to be needed to make the meat paste hold together during cooking and to develop a minimum acceptable level of firmness at the end.

The advent of the use of computer formulation in the 1950's and 1960's led to a critical need for a quantitative "bind" scale of the quality of meats. Experience of the day was codified into an ordinal 100-point scale by the Anderson-Clifton Company, a consulting company in Chicago (Anderson and Clifton, 1967). This scale survives reprinted in a common meat processing textbook, "Processed Meats" by Kramlich, Pearson and Tauber (AVI, 1973) and the second edition by Pearson and Tauber (AVI, 1984, ISBN 0-87055-461-1). In this scale, beef bull meat (full carcass) is 100, beef 85% trim is 90 and beef deckle trim (95% fat) is 5.

The problem with the Anderson-Clifton scale was that it was completely subjective and therefore no proof was evident that it was scaled properly or that the meats involved were properly ordered. The resolution of this issue, of course, entailed turning to science.

EMULSION-BASED MODELS

By 1960, it was becoming an orthodox belief that meat pastes, being as they were a mixture of immiscible fat, water and protein elements, must be an emulsion system, viz., oil-

TABLE 1 – Proximate analysis and functional indices of various meat materials.

Material	Description	Protein %	Moisture %	Fat %	Ash %	Bind Index	Color Index	Collagen/ Protein %
B40	BF 40% Trim	7.8	26.7	65.0	0.5	8.41	14.42	47
B50	BF 50% Trim	9.9	33.9	55.0	1.2	12.28	18.96	42
B75	Bf 75/85% Trim	15.7	57.4	25.3	1.6	21.69	33.63	38
B85	Bf 85/90% Trim	16.8	62.0	20.0	1.2	24.43	38.56	28
BBLOOD	Bf Blood	18.0	80.0	0.0	2.0	15.00	180.00	0
BBULL	Bf FC Bull Meat	19.8	70.7	9.0	0.5	30.01	46.53	20
BCHEEK	Bf Cheek Meat, Trmd	17.3	68.0	14.2	0.5	13.96	47.95	59
BCHEEKTR	Bf Cheek Trim	8.0	29.0	62.0	1.0	3.72	33.98	85
BCHUCK	Bf Bnls Chucks	15.9	57.1	25.5	1.5	23.97	38.43	30
BCLOD	Bf Clods	20.1	72.3	6.7	0.9	26.97	41.65	25
BCOW	Bf FC Cow Meat	18.0	66.1	15.1	0.8	24.48	38.92	21
BDIAPH	Bf Diaphragms	16.7	69.0	14.1	0.2	11.72	32.28	65
BHEAD	Bf Head Meat	17.2	67.9	13.5	1.4	7.78	26.40	73
BHEART	Bf Hearts	16.0	72.7	9.6	1.7	6.10	39.96	27
BLIP	Bf Lips	17.2	71.6	10.1	1.1	0.30	0.48	90
BLIVER	Bf Livers	19.3	69.0	6.5	1.2	2.12	50.09	95
BLUNG	Bf Lungs	18.8	77.6	2.2	1.4	0.33	10.50	50
BPLASMA	Bf Plasma	8.0	90.5	0.0	1.5	15.00	14.80	0
BPLATE	Bf Plates	11.7	42.2	45.0	1.1	16.33	25.22	42
BPROTFR	Bf Protein Fraction	18.1	58.9	22.0	1.0	0.30	4.10	80
BSHANK	Bf Shank Meat	18.9	72.7	7.1	1.3	28.00	46.29	66
BSPLEEN	Bf Spleens	17.9	79.2	2.3	0.6	0.79	60.84	100
BTONGTR	Bf Tongue Trim	8.7	32.4	58.0	0.9	7.03	33.98	64
BTONG	Bf Tongues	16.3	58.4	24.2	1.1	8.34	35.86	60
BTRIPE	Bf Tripe, Cooked	15.9	81.9	2.1	0.1	0.01	0.01	100
BWEAS	Bf Weasands	15.1	79.0	5.2	0.7	1.00	19.40	90
CMEAT	Ck Shredded Meat	13.0	68.0	18.0	1.0	23.94	19.89	35
M90	Mutton, bnls	19.2	69.4	10.2	1.2	22.56	37.29	22
P15	Pk 15% Trim	3.4	11.0	85.0	0.6	3.16	1.20	60
P50	Pk 50% Trim	9.7	34.3	55.0	1.0	11.73	9.02	34
P80	Pk 80% Trim	15.9	57.4	25.0	1.7	19.25	16.59	24
PBACEND	Pk Bacon Ends	7.7	21.2	70.1	1.0	0.08	2.55	86
PBACKBEL	Pk Backfat/Belly Trim	3.2	13.4	82.9	0.5	7.70	5.91	60
PBACKFAT	Pk Backfat, Untrmd	2.3	8.0	89.2	0.5	1.13	0.90	95
PBELST	Pk Belly Strips	6.9	24.7	68.4	–0.0	6.14	4.73	35
PBLADE	Pk Blade Meat	19.2	71.1	9.2	0.5	23.75	19.97	23
PCHEEK	Pk Cheek Meat, Trmd	17.3	67.0	14.1	1.6	8.61	28.66	72
PCHEEKTR	Pk Cheek Trim	3.9	18.1	78.0	–0.0	3.64	21.09	85
PDIAPH	Pk Diaphragms	16.0	65.2	17.7	1.1	15.95	18.11	70
PFAT	Pk Backfat	1.0	3.9	95.0	0.1	0.01	0.01	95
PHEAD	Pk Head Meat	15.3	58.6	25.0	1.1	7.49	15.62	69
PHEART	Pk Hearts	16.1	76.2	6.9	0.8	6.12	32.28	27
PJOWL	Pk Skinned Jowls	6.1	22.6	71.9	–0.6	4.53	1.76	43
PLIVER	Pk Livers	19.7	69.1	7.7	0.5	2.11	49.44	95
PNECK	Pk Neckbone Trim	15.2	54.6	29.1	1.1	18.78	15.74	25
PPIC	Pk Bnls Picnics	16.8	59.4	24.0	–0.2	20.10	15.90	23
PPIC70	Pk Picnic Trim	14.6	53.9	32.1	–0.6	18.19	15.62	24
PPICHRT	Pk Picnic Hearts	18.8	68.2	12.1	0.9	23.01	19.34	22
PREG	Pk Regular Trim	8.9	31.4	58.2	1.5	9.60	8.56	36
PSKIN	Pk Skins	28.3	39.6	32.0	0.1	0.00	0.00	100
PSNOUT	Pk Snouts	14.6	52.3	31.9	1.2	2.50	0.50	80
PSPLEEN	Pk Spleens	16.9	76.3	5.0	1.8	0.74	55.65	90
PSTOMAC	Pk Stomachs, Scalded	13.9	72.0	13.4	0.7	0.01	0.01	98
PTONGTR	Pk Tongue Trim	7.7	27.5	64.9	–0.1	7.11	29.64	72
V90	Veal 90% Trim	19.4	70.2	10.0	0.4	25.00	25.00	30

Sources: J. Carpenter, R. Saffle, H. Ockerman, Anderson & Bell. Used by permission of Least Cost Formulations, Inc.

in-water with the protein as emulsifier. It was conjectured that the fat particles in the paste were surrounded by a dispersed protein in water mixture. The protein was thought to "stabilize" the fat particles during cooking. There was even a belief that over-chopping of the fat particles would increase their surface area to such an extent that the protein could no longer "coat" them, resulting in an "emulsion" breakdown. It was found that the salt-soluble protein fraction (at 1 M NaCl) was the most effective in these functions, so most attempts to develop model test systems started with a salt extraction (Hansen, 1960).

A key development was that of a salt-extraction plus oil titration system (Swift et al., 1961). Meat was extracted with salt solution, the extract blended with fat and additional fat added until phase separation occurred. Results were quoted as ml fat per mg of protein, termed the "emulsifying capacity" of the meat. In subsequent work (Swift and Sulzbacher, 1963), soybean oil was substituted for pork fat.

At this point, Robert Saffle enters the picture. In a seminal article with John Carpenter (Carpenter and Saffle, 1964), the authors described and characterized their modification of the Swift model system.

SAFFLE "GEORGIA BIND INDEX" METHOD

As described by Carpenter and Saffle (1964), the basic method of determining emulsifying capacities of meats is as follows:

1. 75 g of triple ground (3mm) meat was blended with 300 ml of 3% NaCl solution for 1 minute at 12,000 rpm (no load) in an Osterizer with variable speed rheostat. The extract was left standing for 3 minutes, then blended again for 1 minute.
2. The slurry was centrifuged for 10 minutes at 9990 x g. The supernatant was again centrifuged for another 10 minutes for further clarification. The entire process took place in a cold room at 2°C.
3. Protein concentration in the extract was determined by the biuret method.
4. Protein strength was diluted to 10 mg/ml by adding 3% NaCl solution.
5. 25 ml of the adjusted protein extract plus 50 ml of soybean oil was added to a pint jar on the Osterizer with a 9mm hole drilled in the top.
6. The mixture was blended at 13,140 rpm for 30 seconds before continuing oil addition through the hole.
7. The emulsion was tempered for 5 minutes in a 20°C water bath.
8. The emulsion jar was reattached to the blender and blended at 13,140 rpm while oil at 25°C was added at a rate of 0.5 ml/s.
9. Endpoint was reached when a visible breakdown occurred (phase separation in the jar).
10. "Emulsifying Capacity" was calculated as ml oil per 0.1 g of protein in the extract (nominally 10 mg/ml x 25 ml = 250 mg = 0.25 g protein).

CALCULATION OF BIND INDEX

According to Carpenter and Saffle (1964), the measurements for bull meat were 8.17 g salt-soluble protein per 0.1 g meat and 43.32 ml oil emulsified per 100 mg of salt-soluble protein. For this sample of bull meat, the total protein was 21.46% and the salt-soluble fraction was 38.09% of the total protein. For cow meat the numbers are 8.19 and 36.64, respectively, with a total protein of 21.45% and a salt-soluble protein fraction of 38.16%.

Saffle later reviewed the history of the models in his excellent article "Meat Emulsions" (Saffle, 1968). He coined the term "Constant Emulsification Value" (CEV) for the product of the percent salt-soluble protein times the emulsifying capacity.

For cow meat,

CEV = 38.16% ssp/protein x 36.6 ml oil/0.1 g ssp
= 14.0 ml oil/0.1 g protein in meat

For bull meat,

CEV = 38.09% ssp/protein x 43.32 ml oil/0.1 g ssp
= 16.5 ml oil/0.1 g protein in meat

Saffle recommended using CEV times total protein to characterize "bind" qualities of the meat. He believed that CEV would be nearly constant for a particular cut of meat, and that multiplication by protein would account for any variation in proximate analysis of any lot.

Sample values quoted by Saffle in a trade publication are:

Bull meat	16.3 ml oil/0.1 g protein
Cow meat	14.0
Boneless picnic	13.2
50/50 pork trim	13.0
Beef cheek meat	8.2
Pork hearts	11.1
Pork cheek meat	10.7
Beef hearts	9.3
Beef tongues	8.0
Skinned jowls	7.9
Pork tongues	5.2
Pork snouts	0.5
Pork stomach	3.4
Beef tripe	3.1

Obviously, the actual CEV will depend on 1) the salt-soluble protein percent and 2) the ml oil emulsified per 0.1 g salt-soluble protein. The actual "bind" value will also depend upon the protein content of the meat.

Eventually Saffle left the University of Georgia and Carpenter took over as custodian of the model results data. Table 1 summarizes the results (corrected) provided by Carpenter upon request from the industry.

Examination of Table 1 will show a discrepancy between the values quoted by Saffle and the "Bind Index" shown. For example, Saffle quotes 16.3 as the CEV of bull meat and 14.0 for cow meat. Carpenter's table provides 30.01 and

24.48 respectively. The cause of the discrepancy and the actual discrepancy itself are critical, but unknown to most, if not all, in the meat industry: at some point after Saffle left the University of Georgia, Carpenter rescaled the "bind index" numbers to represent emulsifying capacity in grams of oil (specific gravity 0.93) per gram of meat, not protein.

This entailed multiplying Saffle's CEV by 10 to correct 0.1 g protein to 1 g protein in the denominator, followed by multiplication by 0.93 to convert ml oil to g oil and by the total protein content. For example, for bull meat:

Bind Index = 163 ml oil/1 g protein x 0.93 g oil/ml
x .198 g protein/g meat
= 30.01 g oil/g meat

Carpenter's bind index values now incorporated the actual protein content of the lot of meat tested. No longer could it be expected that the bind index would be a constant of the particular type of meat, as was Saffle's CEV.

Unfortunately, Carpenter did not publish or explain his change in scale to the industry at large, or even to the academic community. To this day, most published works and most industry users continue to multiply Carpenter's bind index values by the meat protein content, as taught by Saffle. This is clearly erroneous, since Carpenter has already carried out this operation.

Figure 1 shows a plot of the data in Table 1 for Bind Index vs Bind (= Bind Index x Protein). Note the good linear fit with a coefficient of determination of 0.94. By a lucky accident, Bind Index and Bind (= Bind Index x Protein Content) are almost statistically identical to each other, so little error results from the mistaken second multiplication by protein. The use of Bind to characterize each meat's contribution to texture has been found to work empirically in numerous operations over the last 30 years. This is particularly surprising in light of the scaling error usually made (second multiplication by protein) and the discrediting of the underlying emulsion model. There was no causal connection established between Saffle's emulsion measurement and the cooked product texture. It seems in the end merely to be an elaborate scheme to determine the functional, non-collagen protein content of meats (see Figure 2).

FURTHER DEVELOPMENTS

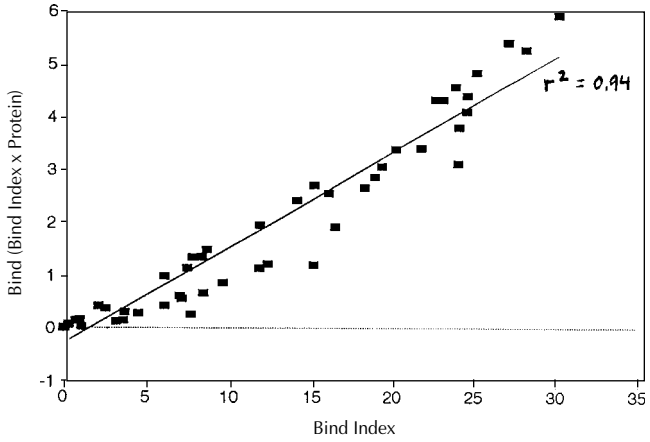
The QC Assistant commercial product (1983, Least Cost Formulations Ltd., Virginia Beach VA) incorporated "LaBudde Equation" models of the bind index, which allowed estimated values knowing only part of the meat's chemical analysis (moisture, fat or protein) and its species and general type. This adjusts the bind index to suit the variation of a particular lot in proximate composition (as per Saffle's original intention) and has made the use of "bind index" values in industry much more practical and effective.

Parks et al. (1985) similarly published regression fits which predicted bind index values for a variety of meats, based on protein or moisture content (similar to the QC assistant/LaBudde Equations).

J.D. Porteous (1979) re-determined "bind constants" for Canadian cuts of meats using the Carpenter and Saffle procedure. Porteous included an "emulsion stability" factor in his constants, so they do not compare directly to the Saffle or Carpenter values. Consequently, they have been little used in the industry.

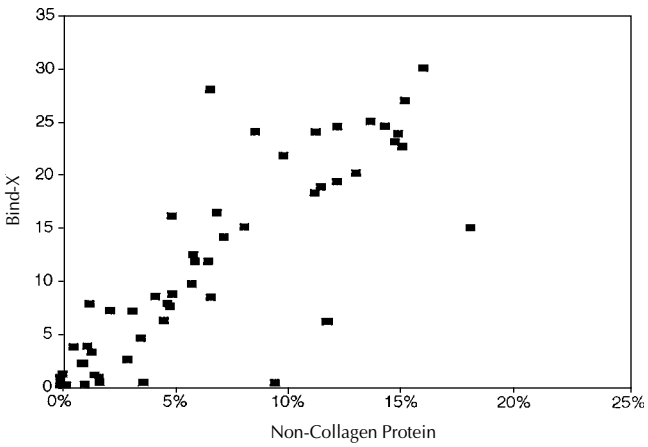
Several shortcomings to the Georgia bind index value approach have become apparent. Over the years, many companies have unsuccessfully sought to update the bind index values to reflect differing compositions of meats. This is due in part to poor documentation of the original bind index value determination method, but also because the method is tedious and difficult to reproduce. Also, the method is only useful for meats, not non-meat ingredients like soy protein, starch, gums, etc. Bind index values for these have only been estimated from experience (Comer, 1979; Comer and Dempster, 1981).

FIGURE 1.



Plot of Bind vs. Bind Index Values, showing approximate linear relationship of the data.

FIGURE 2.



Plot of Bind Index (Bind X) versus non-collagen protein content, from Table 1.

The method is based on the oil emulsifying ability of the meat protein. While no one can refute that protein coating of fats is involved in the early stages of frankfurter and bologna manufacture (but is this emulsification? See Lanier, 1985, and Amundsen, 1994), the finished cooked product certainly resembles a protein gel more than an oil-in-water emulsion like mayonaise. Acton et al. (1983) reviewed the underlying models in meat systems and came to the conclusion that a simple emulsion model was incorrect, but instead that protein-water, protein-fat and protein-protein interactions were all important. Since this time, the emulsion model of meat systems has generally fallen into disfavor with the consensus now becoming focused on the gelled proteins of the cooked product (Regenstein, 1989; Gordon and Barbut, 1992; LaBudde, 1992; Amundson, 1994).

Truly scientific "bind" values are presently being determined based on regression of mechanical testing data of the mechanical failure (texture) properties of cooked model (filled, composite) gels. This approach to measuring meat ingredient functionality was first proposed by Lanier (1985), while similar approaches were also suggested by Comer and Dempster (1981) and Regenstein (1989). Actual development of this approach into a method of testing did not proceed until funded by the National Live Stock and Meat Board at North Carolina State University early in this decade (Lanier et al, 1993; Lanier and LaBudde, 1993). From these studies a method has developed based on measurement of the effects which each ingredient exerts on the gelling properties of the blended muscle food. This work has demonstrated that a relatively rapid and reproducible method, based on the Torsion Gelometer testing apparatus, can more accurately and completely assess the "bind" contribution of meat or meat/non-meat components of a blend.

"BIND" VALUE (FUNCTIONALITY COEFFICIENTS) DETERMINATION FOR MEAT INGREDIENTS BY TORSION GELOMETER APPROACH

Each ingredient to be tested (three total) is substituted into a formulation composed of a lean, quality meat (bull meat or turkey breast, for example), a fat source (generally we have used lard), water, salt and polyphosphate (optional). Formulations of this and subsequent mixtures with the ingredient are held to constant fat and protein levels.

The ingredient being tested is added into the formulation incrementally, and lean meat, lard and/or water are removed to maintain fat and protein at constant levels. An exception would be in evaluating functionality of a carbohydrate material, such as starch or carrageenan, which would substitute for total non-fat solids and water in the formulation. In this case, total non-fat solids, not protein content, as well as fat content would be held constant.

Often the levels used of an ingredient in this testing may exceed those normally used in industry, in order to determine the linear effect of their addition. This enables a more accurate assessment of their additive effect at lower, more realistic levels of addition. An arbitrary upper cut-off for incorporation of a test ingredient is when greater than 10% cook loss is measured.

Batters are developed by first comminuting meat(s), salt, phosphate and at least some of the added water in a Stephan UM-12 vertical cutter-mixer to 5°C, then adding any dry test ingredient with the remaining water, plus fat (lard) and chopping in the UM-12 to 15°C, finally passing this mixture through a Stephan Microcut mill to obtain a finely divided batter at 20°C, ±2°C.

For cooking, batters are stuffed into stainless steel or polycarbonate tubes, capped, and processed in a waterbath at 50°C for 30 min., followed by 70°C for 45 min. (to simulate a conventional smokehouse cook). The cooked gel product is then cooled briefly in an ice bath to near 25°C.

Cook losses are measured by weighing the tared tubes prior to and after stuffing, then pouring off cook loss after cooking and cooling, finally blotting the cooked gels and wiping the inside of the tubes before weighing each gel and its cooking tube together.

The mechanical properties of the cooked, cooled (measured at 23° to 25°C) gels at fracture are determined by testing on a Torsion Gelometer (Gel Consultants Inc., Raleigh, NC). Unlike conventional texture testing machines, torsional testing yields fundamental test values of stress and strain, which correspond to the strength and the cohesiveness (ductility) of the gel, respectively. It is the only test geometry that yields these measurements independent of one another, an especially important factor when measuring gel strain (Hamann and Foegeding, 1995).

A plot of stress vs strain provides a textural "map" for monitoring process and formulation effects on product texture (Fig. 3).

The functionality coefficients ("bind" values) can be obtained by regressing the stress, strain, or cook-loss values versus the % weight fraction of the test material (Fig. 4), according to the relationship:

$$X = \alpha LM + \beta TM$$

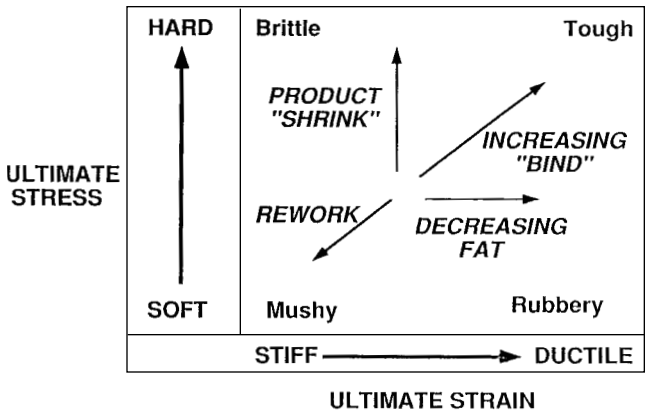
where X = stress, strain, or cook-loss
LM = standard lean meat, weight fraction in formulation
TM = test material, weight fraction
α = coefficient for standard lean meat
β = coefficient for test material

If only two data points existed, X_1 and X_2, corresponding to the control formulation (no test material added) and the formulation containing the maximum level of incorporation of the test material, respectively, then the coefficients α and β could be solved by constructing two equations with two unknowns:

$$X_1 = \alpha LM_1 + \beta TM_1$$
$$X_2 = \alpha LM_2 + \beta TM_2$$

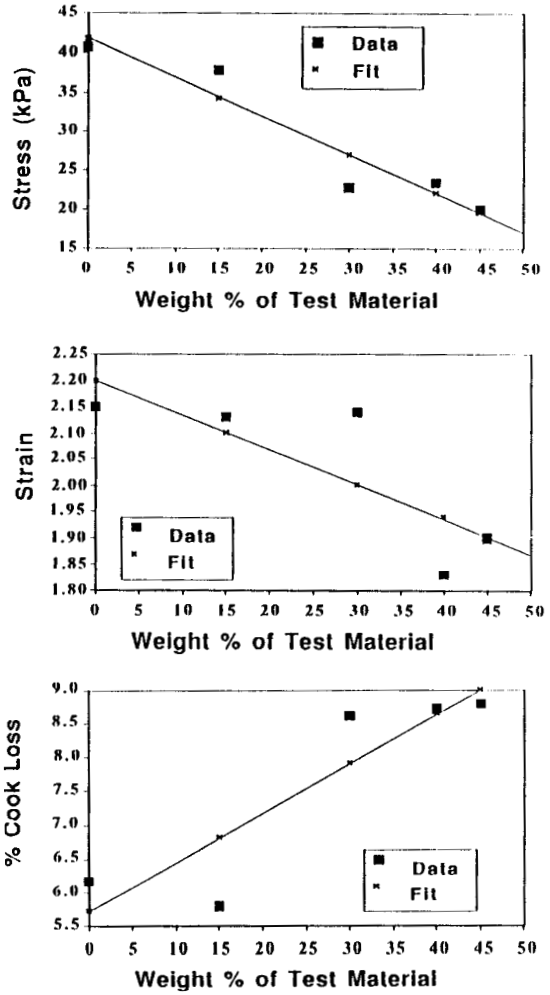
Since $TM_1 = 0$, it is simple to first calculate a value for α

FIGURE 3.



Torsional texture "map" from plot of stress vs strain. Descriptors in corners of this plot indicate the common terms consumers would use in describing texture of gels in this region relative to other regions of the plot. Arrows show the general effects that common process or formulation changes have on frankfurter texture.

FIGURE 4.



Examples of plots and regression fits of data obtained for product stress, strain, and cook-out (per unit protein) versus weight % content of a test material, used in developing functionality coefficients for prediction of effect of test ingredient addition on product stress, strain and cookout.

in the first equation, then substitute this into the second equation to determine β.

These coefficients are then used in any subsequent formulation involving these two materials, the lean meat and the particular tested ingredient, to predict the stress, strain and cook-off of formulations containing them. The functionality of a tested meat or other ingredient is not expected to change with regard to the meat(s) in which it is blended.

By first torsion testing successful commercial products, a "target" window for acceptable texture can be established on the torsional "texture map" (Fig. 5). By application of the stress and strain functional coefficients in linear programming, the product can be formulated to fall exactly within this target window of acceptability for texture while minimizing cook loss and ingredient costs. This is a substantial improvement over the old bind index value system, for which no causal connection to product texture had been established. Additionally, it does not necessitate extractions of salt-soluble protein (applicable only to meat ingredients) and the finished product can be tested to insure accuracy of the predicted values.

We envision that meat processors will be able to make more intelligent decisions regarding ingredient selection by utilizing this approach to assess the true binding characteristics of the many ingredient materials available for comminuted meat products.

VALIDITY OF THE TORSION GELOMETER APPROACH TO FUNCTIONALITY ("BIND VALUE") ASSESSMENT FOR LINEAR PROGRAMMING

An initial study validated the preparation and cooking procedure for testing given above, indicating only a slight bias in relating results obtained in the test cooks with that obtained in frankfurters prepared in a conventional commercial smokehouse. Differences were attributed to shrink effects in the smokehouse (Lanier et al., 1993).

Subsequently, two sets of lots of 4 meats were used in preparing 21 cases of blends spanning all second-order and most third-order terms in a mixture polynomial design. Torsional stress and strain plus water loss on cooking were measured. The results indicated that the stress and strain values were predicted to within duplicate error by using only the linear terms of the meat composition (no interactions) (Lanier et al., 1993).

Also, four lots of 4 meats were tested in constant fat (25%) and protein (10%) formulations, typical of American frankfurter production, in combination with bull meat, per the testing regime for functionality assessment described previously. Each mixture case was completely replicated 2 to 4 times. The results indicated that average stress, strain and cook losses for each case were predicted to within case replicate error, using only the linear terms in fractional meat composition (Lanier et al., 1993).

A final study evaluated 12 different fresh and frozen beef skeletal and variety meats (versus bull meat) using the same torsional testing approach to measuring functionality coeffi-

FIGURE 5.

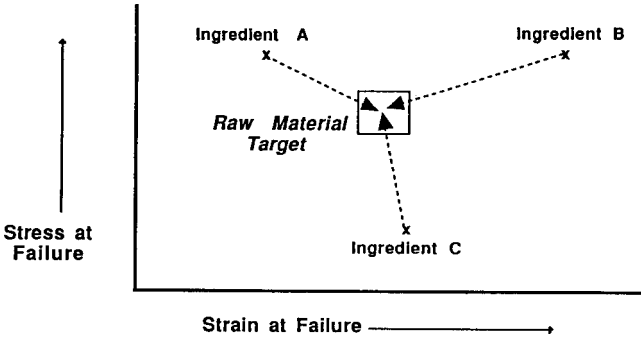


Illustration of blending of ingredients to meet a desirability target on the torsion texture map.

cients. This study again proved the linearity of stress, strain and cook loss values in blending applications (Lanier and LaBudde, 1993).

Stress values measured by the torsion method in this study were found to be highly correlated with the commonly used University of Georgia bind index values. This indicates not only that the bind index values do have relevance to product texture (though more poorly predictive of product cohesiveness or cook loss), but that a changeover from this commonly used system of functionality/bind assessment would be straightforward and risk-free.

The new torsion/gel-based approach to bind assessment does, however, have several great advantages:

1. *Causality:* Bind coefficients are based on measurements of a finished product (highly predictive of actual smokehouse product), not results of testing a model system. Furthermore, the test system derives from recognition that protein gelation and entrapment of constituents, rather than emulsification of fat, is the primary determinant of product stability and texture.
2. *Validity:* Rather than a vague "bind assessment", prediction of actual product attributes (texture, liquid retention) is made by the new bind coefficients. Predicted results can be easily validated by measurements on the finished product.
3. *Applicability:* The former approach to bind assessment was limited to meat materials. Functionality of other ingredients could only be estimated, not directly measured. With the new approach, all ingredients can be accurately assessed for their effects in blended meat products. This immediately establishes the true value of each ingredient to product texture and stability. Recently, we have successfully applied this approach to measuring the functionality of beef plasma, soy proteins and carrageenans (as yet unpublished).
4. *Repeatability:* The new test is based on well-defined, fundamental test methods derived from material science and engineering. The former bind test method was not only tedious, but notoriously sensitive to small variations in procedure, to the extent that it could not be practically used to update bind coefficients for new ingredients or ingredients that may have suffered changes during handling or storage.

SUMMARY

The value of least-cost, linear programming of comminuted meat formulations has been recognized by many companies that have benefited from its routine use since the approach was pioneered by the University of Georgia in the 1960's. Fundamental to its use is the requirement to assess the functionality, or "bind" potential, of the component materials of a meat blend. Despite what most would regard as faulty reasoning in basing this bind assessment on the ability of meat proteins to emulsify vegetable oil, it is apparent from the recent studies of the authors that the Georgia bind index values do have predictive value with respect to finished product texture. This is probably because both oil emulsifying ability and gelling ability require undenatured myofibrillar protein; thus both tests can estimate the quality of extracted protein.

The shortcomings of the Georgia bind index approach are considerable, especially with regard to east of reproducibility and applicability to non-meat ingredients. The new torsion-based gel approach to functionality assessment overcomes these problems, and additionally yields accurate functionality coefficients that predict both primary mechanical aspects of texture (stress, strain), plus cook loss. It is our hope that with this new approach, suppliers to the comminuted meat industry can begin to more accurately characterize their ingredient materials with respect to functionality, with the result that useful "bind" coefficients can be generated for general industrial use. Similarly, ingredient materials that are subject to high variability in functionality, such as stored meats or other ingredients, can be spot-checked by this more straightforward testing procedure to accurately assess their functionality at time of use.

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PROTEIN SUMMARY

Question: In your model system, can ultimate texture of the product be affected by the temperature and temperature schedule?

Lanier: Yes, it certainly can. The methodology of bind value which I have described simulates a typical actual meat processing temperature program very well. You need to establish a correlation between this method and what is actually going on in your plant by comparing the results with *your* own plant, considering your cooking methods and equipment.

Question: In your work, how different is this method to what we have been using? If you prepare frankfurters or sausage using your values versus using previous methods, such as the modification of Saffle's method, what difference does it make?

Lanier: Based upon our work, which was supported by the National Live Stock and Meat Board, we found that there is a very close correlation between the stress functionality coefficient and the Georgia bind value measured by Dr. Carpenter's group. The correlation between the strain and cookoff coefficients and Georgia bind value is not as great. So in a way, this validates the Georgia method; i.e, this method could be used to predict the Georgia bind value for a meat or any other ingredient (and Georgia bind values cannot be obtained for non-meat materials). However, you also get the strain coefficient that will predict the ductility of the material, which is important for such things as sliceability and texture. Additionally, the cookout coefficient gives you information about the yield.

Question: How would the processing plant operator actually use the information which you are providing? Would he combine them into a single value or pick the one felt to be most important?

Lanier: One of the most important points here is that you do get the three values of stress, strain and cookout as individual parameters, and they are not combined into a single value, as Saffle's bind value combines emulsifying ability and salt solubility. Thus, a processor would select the parameter or parameters that are most important for the product being formulated. A major advantage of this procedure is that you can verify, quantitatively, whether you have actually achieved the stress, strain or cookout predicted by the computer for a formulation. We found in commercial plant trials that we were able to predict these parameters very well.

Question: What does this all mean to me? How can I use this? How much will it cost me? What are the benefits?

Lanier: This method more precisely and quantitatively characterizes the functional properties imparted by raw ingredients to better predict finished product characteristics important to processors and consumers. Ingredient suppliers are continually developing new non-meat ingredients for use in sausage products. This method gives a "hard number" handle on those ingredients to predict the real benefits that would be accrued by their use in meat product formulations.

Question: The processor wants a simple number to use. Does this new method you have described simplify that?

Lanier: No. As I have said, this method does not give a single number but rather gives several values that can be used in predicting functionality of meat and non-meat ingredients. This does not present a problem, however, since computers can handle the greater numbers that are generated by this method and available to the processor. With computers, we no longer have to deal with just a single bind value.

Question: Have you been able to verify your new method by having the equipment distributed in plants to be put on trial?

Lanier: We are still just at the presenting stage to get people interested in the procedure. This is the first time that we have really tried to introduce this method and its potential in such detail, in a setting where people can really hash it over. Hopefully, from this point we can interest the industry in doing these types of tests.

Question: It is known that we have to be really careful regarding frozen storage of raw materials because of the detrimental effect on functionality such storage can have on use in sausage products. Have you looked at frozen storage

effects in the gelling characteristics of, for example, surimi in order to get a prediction of the curve of time of frozen storage versus functionality? How does freezing relate to bind value?

Lanier: This is talked about pretty well in Saffle's 1968 paper where he mentions a resulting decrease in bind value of about 10% due to frozen storage. In recent work in our laboratory, we have seen greater than a 10% reduction in gelling ability — nearer to a 20% drop. This is one reason why we have been involved in adding cryoprotective additives, the same way as is commonly done in surimi, as a means of protecting the functional quality of the meat. With those materials, we can produce a meat that can function as well as pre-rigor materials. But, no, we cannot predict how much it will change, since it depends on how the meat is handled, and procedures are not the same in all plants. We can, however, measure the effect of freezer storage on any lot of material prior to its use as a sausage ingredient.

Comment: You need to be careful in your discussion not to imply that you lose so much in freezing. Freezing certainly does have an impact, but the meat continues to decline in functionality as the length of storage time increases. So you need to consider that if you determine values by your method, then hold meat in frozen storage, these values will continue to change.

Lanier: This is certainly the case, and there is a danger in determining values at one point and expecting them to still hold at another point. For example, it has always bothered me to some extent to obtain bind values from a table. The point is that, with our test method, you have the advantage of being able to compare sources of meat from several suppliers. If there is a difference, you could then go back to the supplier and argue that, from your perspective, the value of that ingredient is not as good as is represented. This is not to say that you would want to run the test on every batch of meat, but you could periodically check on the quality of meat being sent by a particular supplier.

Comment: I think that one of the advantages of your new test is that you are able to measure interactions within the formulation system. It is not just a characteristic value, or a bind value or a rheological value, but rather you will have interactions between these that you will be able to see by the method you have described.

Lanier: One of the most interesting things about this is that, even though we based this on the gelation phenomenon which is occurring, it may be that emulsification is taking place as well to some extent. Our method does not prove the mechanism of fat and water binding one way or the other. The point is that the method takes into account all of these factors and interactions which might be going on in the product.

Question: To follow up an earlier comment, it must be stressed that bind value for mechanically separated meat, for example, is influenced by many processing factors, such as the machine used, abuse of the raw product, the part of the carcass from which the boned material is received, etc. Therefore, is it really possible to give a bind value in a general sense for a particular meat item?

Lanier: Mechanically separated meat, like surimi, is very much process-affected. Unless you have very consistent raw material and a very consistent supplier, you will be getting variability in the resulting meat and in the bind values for that meat.

Comment: My point is that you would be getting four different values for four different suppliers on their various mechanically separated meat products, as well as different answers for various non-meat ingredients obtained from several suppliers. You cannot treat them generically.

Lanier: I agree. It is especially true for the non-meat ingredients since each meat supplier has his own procedures for the manufacture of these ingredients, whether it be starch, carrageenan, etc. And even within a supplier, it would be nice to know how much variation there is over time with that supplier. A test like this gives you the ability to spot-check things to see if functionality parameters are constant or are changing.

Comment: It seems to me from what you are saying that your procedure gives us more information than did the old bind value, such as determining texture. If this is true, and we continue to go toward more low-fat products and do this by adjusting water, this will be an extremely useful method.

Question: If you are going to be concerned about fat in products, you also need to be concerned about the type of fat. How can the information on your method versus the Georgia bind value help us to understand the theoretical background and basis for cooked finely-chopped sausage?

Lanier: I am not making a claim that our methodology validates the gelation theory of manufacturing of these products any more than that the proven usefulness of the Georgia bind value validated emulsion theory. This is where the two different tests came from, and this is the way the tests developed the way they did. It would be a different discussion to answer the question of what is the evidence supporting gelation or emulsion theory. Some people look at the structure of a finely-chopped sausage as an emulsion, with the interfacial protein film layer surrounding the fat globules. Others consider this layer to be a form of mini-gel that entraps the fat.

Question: Could you make a few comments on the torsion technique?

Lanier: [Dr. Lanier showed a short video which illustrated the equipment and procedures very well.]

Question: What is the predictive value of your method relative to what actually happens in the processing smokehouse?

Lanier: It is not possible, using our method, to predict absolutely what the results will be by a particular processor in a particular smokehouse. Rather there will be a correspondence, whereby stress-strain properties in the test product correspond to those in the final product. Thus, for any particular processor and equipment, changes in values obtained using our method will correspond to changes, im-

provements or not, in smokehouse results, although predicting the absolute numbers may not be possible. This is very similar to the situation with surimi whereby differences in surimi quality, as judged by our technique, correspond to quality of products manufactured with that surimi. This is the predictive value of this methodology. The relationship could be between stress-strain and cook-off in the smokehouse, so that as one goes up, perhaps the other goes down. And you can establish what actually occurs within your own operation.

Question: Regarding manufacture of dry sausage, there is gel formation involved in these products as well. Will your methodology work in predicting texture of these products?

Lanier: We have done some recent preliminary work with dry sausage. Indications are that, once you remove the hard outer portion of the sausage, the methodology works very well for evaluating texture. This is very surprising, considering that a presumption of the procedure is a homogeneous distribution of particles and non-directionality of those particles; that is, an isotropic product. Obviously, a coarse ground product like dry sausage has neither of those attributes. However, we were obtaining fairly reproducible results with our instrumentation and method on a dried sausage snack stick.

Question: If you get meat bind values for different cuts and you put them all together into an equation, do you have an additive situation or are they independent of each other?

Lanier: We do have additivity. When I talked about validating the procedure, this was the main point that we were looking at. Even if interactions do exist, these can be ignored and additivity assumed, and good predictability of results is still obtained. In other words, non-linear interactions certainly exist, but they do not preclude linear programming for least-cost formulation. [There was disagreement on this point between Dr. Lanier and the questioner, Dr. Eva Tornberg]

Question: What is the cost for getting set up with this equipment?

Lanier: This equipment is now commercially available with the sample preparation grinder for about $12,000, about the same price as an inexpensive Instron. By the time you buy a computer with it, you may have a cost of about $15,000.

Question: Have you done any studies relating to sliceability?

Lanier: Users of this equipment have found that the sliceability is very related to the ductility, the strain value. So strain is related not only to hardness but also to sliceability.

Question: Does the Georgia bind value reflect the extractability of the proteins?

Lanier: The Georgia bind value reflects the extractability times the oil emulsifying ability. The oil emulsifying ability is really showing you the quality of the protein. And this is probably the same quality of protein that makes a good gel. However, in evaluating model systems, you must be concerned with whether you are measuring the contribution of water-soluble or salt-soluble proteins, since they differ markedly in their functional properties, with respect to emulsification or gelation properties.

Question: How did you work to reduce the variability in your stress coefficient measurement?

Lanier: The major thing you have to pay attention to in order to reduce that variability is air bubbles. From a statistical standpoint, in our method we drop the high and the low values, due to the problem created by air bubbles. Of course, this is assuming that we have a normal distribution. This may, in fact, not be the case. There is also variability due to the instrument. It appears that the best we have been able to do is to reduce variability to about 10%, in stress values (much less in strain) which turns out to be good enough.

Question: At what temperature is your model system testing run, and is this temperature critical?

Lanier: Actually, temperature is critical. Most of our tests on cooked gels are run at room temperature, about 23° to 25°C. If this is not available, there is a water bath associated with the torsion testing device that can be used to control temperature closely. The water bath can also be used at determining differences in values at different sample temperatures. This is useful to understand, for example, how the texture of a warm hot dog differs from one at cooler temperatures.

Question: How would this method and instrumentation be used in an actual meat industry operation? That is, what is it useful for?

Lanier: For the purpose of least-cost formulation, it would be a way that you could determine bind values or the functionality coefficients for both meat and non-meat ingredients. These results could then be tabulated, and you could assume that every lot of meat or ingredient of like nature would have similar bind values, similar to what Saffle did. This would be all right to do unless you had reason to suspect that different suppliers were providing samples with different characteristics, such as frozen versus non-frozen meats. The torsion method could also be just used for overall general quality control, as is now being done by one of the major hot dog manufacturers.

Question: What are the advantages of your new method over other rheological texture-testing methods?

Lanier: Our method has been shown to be better than the Japanese punch test and the Instrumental Texture Profile Analysis test to determine mechanical texture characteristics related to sensory properties. The best correlation with texture properties was obtained with this method. Comparing our method with torsion, compression and tension methods, one advantage is our method is applicable over a wider range of gel properties. Compression is really only useful in relatively weak gels, and tension is only useful in very strong gels. And neither one of these gives the complete separation of the stress and strain. Our method gives these as independent measurements.