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Summary and Implications

Reduced-lean pork trimmings (~70 percent fat and 30 percent lean) have low economic value due to inherent high fat content. Mechanically modified pork skin was used to extend reduced-lean pork trimmings by making a fat emulsion gel, lowering fat content by dilution in an attempt to increase the value of reduced lean trimmings. The first objective was to extend reduced-lean pork trimmings by creating a pork skin fat emulsion gel (FG) and to characterize and optimize the functionality of FG from combinations of pork skin, reduced-lean trimmings and added water (AW). The next objective was to incorporate the best FG into low-fat bologna. Fat emulsion gels were characterized and optimized using combinations of pork skin (3 to 10 percent), AW (25 to 50 percent) and reduced-lean pork trimmings (20 to 40 percent final fat content). To make FG, flaked pork skin and water were chopped and heated to 160°F to solubilize collagen. The cooled (<85°F) skin/water mixture, combined with reduced-lean trimmings and salt (4 percent), were then chopped to 105°F. Regression analysis predicted optimal emulsion stability (lowest ml fluid released/100g of FG during simulated cooking) in FG occurred with 5 to 6 percent pork skin. Incorporation of selected FG, with known characteristics, into low-fat comminuted pork products could improve water binding properties and help achieve desired sensory properties when used at appropriate levels. It was determined FG should be formulated with 6 percent skin for optimal functionality and at least 30 percent fat to utilize more reduced-lean trimmings. Pork skin fat emulsion gels with the best emulsion stability [30 percent fat, 25 percent added water (AW)], the best hydration/softest texture (30 percent fat, 50 percent AW) and the most economical FG (40 percent fat, 50 percent AW) were selected to evaluate how FG with known characteristics would impact low-fat/high-added-water bologna. There was a low-fat/high-added-water control (10 percent fat/30 percent AW) and a 30 percent fat/10 percent AW control. Common problems associated with low-fat/high-added-water bologna include dark color and soft texture. The texture of bologna containing FG was improved, it required more force to fracture and was harder ($P<0.05$) than control low-fat/high-added-water bologna but similar ($P>0.05$) to the full-fat control. The sensory panel found bologna containing FG was more like the full-fat control bologna and had a lighter ($P<0.05$) color and a more ($P<0.05$) springy and firm texture than the low-fat/high-added-water control. The value of reduced-lean trimmings could be increased by production and incorporation of fat emulsion gels into comminuted meat products.

Introduction

Reduced-lean pork trimmings, composed of about 70 percent fat and 30 percent lean, still contain valuable lean that functions to bind water and emulsify fat. It is difficult for processors to utilize reduced-lean trimmings because the lean is embedded in an excessive amount of fat. Also, because it is expensive to remove the lean by trimming with a knife to make a product that consumers will accept, reduced-lean trimmings have low economic value. Flaked pork skin has been shown to bind as much as 600 percent added water (AW) when heated to 160°F and cooled to form a gel. Incorporation of pork skin gels into comminuted meat products improves water binding properties and enhances sensory characteristics by reducing hardness and increasing juiciness of low-fat bologna. Pork skin could be used to extend reduced-lean pork trimmings by binding AW in a fat emulsion gel (FG). The resulting FG would have lower fat content by dilution and would be easier for processors to use in sausage-type meat products. The value of reduced-lean pork trimmings may be increased if FG has texture modifying attributes useable in ground and emulsified meat products. By characterizing FG, it may be possible to create a comminuted meat product with desired texture properties by utilizing a selected FG (with known texture characteristics) as a raw material ingredient.

The demand for low-fat comminuted meat products led processors to remove fat from sausages, resulting in a hard, dry product. To replenish moisture in low-fat sausages, up to 30 percent water has been added. Previous research indicates that as fat was replaced by water, bologna containing 30 percent added water and 10 percent fat was darker in color, softer,

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more juicy and had increased problems with purge compared to full-fat bologna. It was hypothesized that incorporation of selected FG into low-fat/high-added-water bologna could modify functional and textural attributes of low-fat/high-added water meat products, increasing the value of reduced-lean trimmings. The objectives of this project were: to develop and characterize the functional properties of pork skin fat emulsion gels, to determine the combination of pork skin, reduced-lean trim and added water that optimizes the functionality of reduced-lean trimmings and to determine how selected pork skin fat emulsion gels would impact water binding, texture and sensory properties of low-fat/high-added-water bologna.

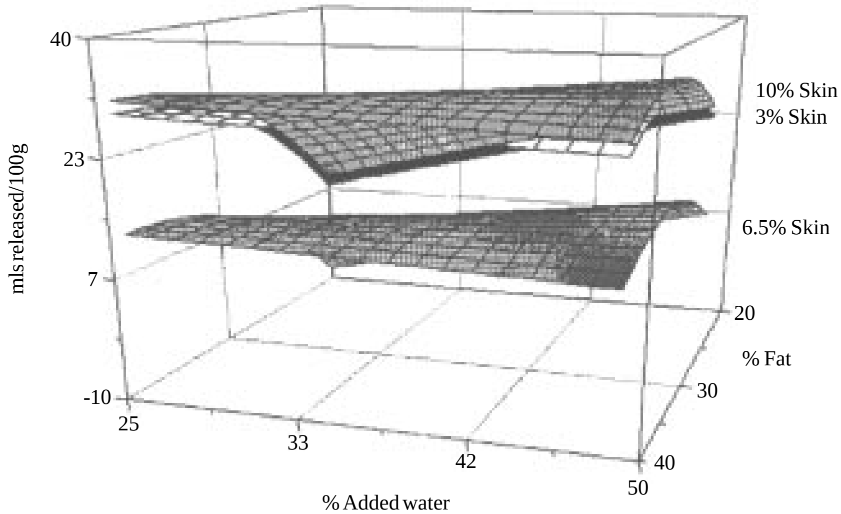

Figure 1. Predicted emulsion stability: total liquids released/100g.

Materials and Methods

Fat Emulsion Gel Characterization and Optimization

A 2^3 face-cube response surface experimental design determined combinations of pork skin (3 percent, 6.5 percent and 10 percent), AW (25 percent, 37.5 percent, and 50 percent) and reduced-lean pork trimmings (20 percent, 30 percent and 40 percent final fat content). Flaked pork skin and water were chopped in a steam-jacketed bowl chopper and heated to 160°F. After cooling the pork skin mixture below 85°F, reduced-lean pork trimmings and salt (4 percent) were added. The batter was chopped to an end point temperature of 105°F and samples collected for proximate composition, pH, hydration (raw batter water-binding ability), emulsion stability (water- and fat-binding ability during simulated thermal processing) and collagen content.

The objective texture attributes of fracturability, hardness, cohesiveness, springiness, chewiness and gumminess were determined by crushing three 1.5" x 1.5" x 0.5" samples to 25 percent of original height two times on a flat surface plate. Hardness measures the force it takes to crush the sample while springiness is a measurement of how much the sample springs back after being crushed one time. Gumminess and chewiness are calculated from values determined for hardness, springiness and cohesiveness. Lee-Kramer shear was conducted on five 2" x 2" x 0.5" samples from each treatment and the peak force to shear and total energy to shear were calculated.

Fat Emulsion Gel Incorporation

It was determined FG should be formulated with 6 percent skin for optimal functionality and at least 30 percent fat to utilize more reduced-lean trimmings. Pork skin FG with the best emulsion stability [30 percent fat, 25 percent added water (AW)] or best hydration/softest texture (30 percent fat, 50 percent AW) properties and the most economical FG (40 percent fat, 50 percent AW) were incorporated into low-fat/high-added-water bologna. The experiment was conducted using a randomized complete block design and replicated three times.

Each FG was mixed for five minutes with ground pork trimmings (96 percent lean) and water to contain 10 percent fat and 30 percent AW and then passed through an emulsifier. Two control pork bologna formulations (without FG) contained 10 percent fat/30 percent AW or 30 percent fat/10 percent AW and were manufactured identically to bologna containing FG. Analysis of raw bologna batter included back extrusion, proximate composition, collagen content and emulsion stability. Bologna was thermally processed to 150°F and cook yield was determined. Additional analyses included purge (meat juice accumulated in bag after storing for 21 or 42 days), expressible moisture (moisture expressed from meat using centrifugal force at zero, 21 and 42 days), objective color (lightness, redness, yellowness, cured color intensity) using a Hunter Labscan Colorimeter and compression and Lee Kramer shear using an Instron.

An eight-member, experienced panel was used to evaluate the bologna for appearance, texture and flavor. The texture of bologna samples was evaluated for resistance to bite (force required to bite through sample), springy/rubbery (amount sample springs back to original shape when compressed with molars), cohesiveness (amount that sample sticks together and forms a ball in mouth), adhesiveness (amount that sample sticks to teeth and roof of mouth) and juiciness.

Results and Discussion

Fat Emulsion Gel Characterization and Optimization

Response surface regression analysis used for pork skin levels of 3, 6.5 and 10 percent predicted optimal emulsion stability (lowest ml fat and

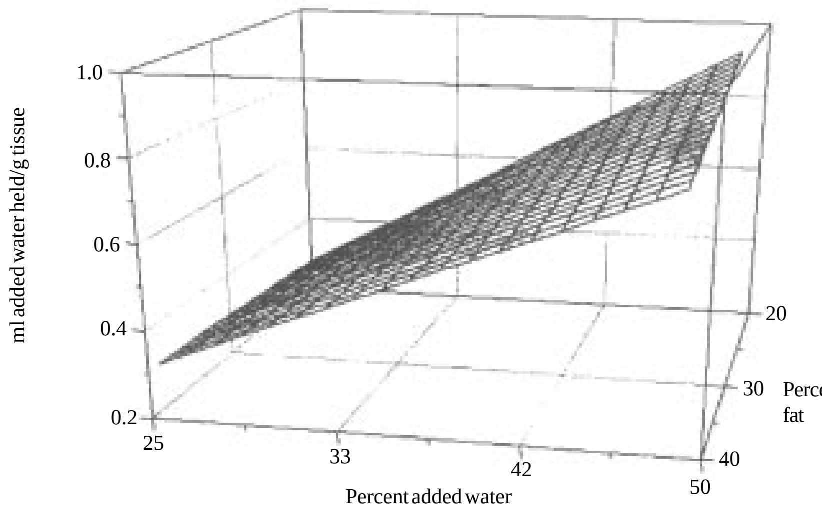

Figure 2. Predicated fat emulsion get hydration.

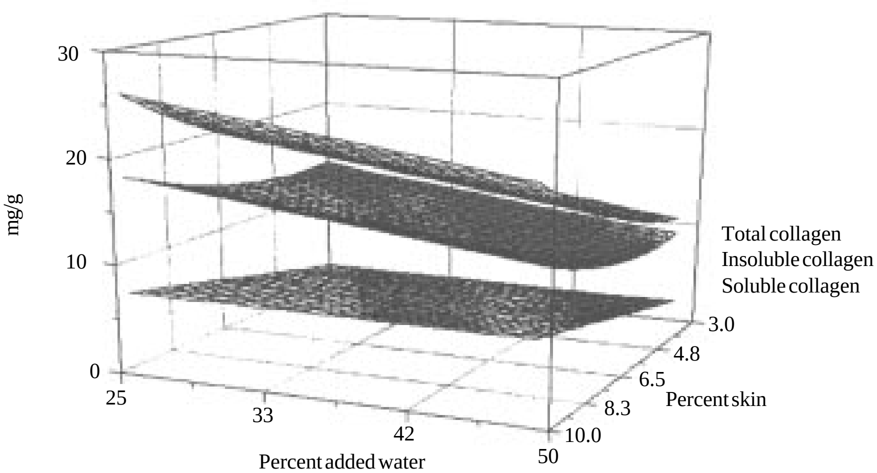

Figure 3. Collagen content in fat emulsion gels.

gel water released/100g) in FG occurred with 6 percent pork skin. Emulsion stability decreased as fat level and AW increased to 40 and 50 percent, respectively (Figure 1). Predicted hydration values (water binding capacity) of raw FG batter increased linearly (P<0.05) from 0.28g water held/g tissue at 25 percent AW to 0.96g water held/g tissue at 50 percent AW (Figure 2).

Soluble collagen, insoluble collagen and total collagen concentration of FG increased (P<0.05) as percent pork skin increased and total and insoluble collagen values decreased (P<0.05) as AW increased (Figure 3). The cohesiveness of FG decreased as percent pork skin increased (P<0.05). FG soluble collagen was correlated (P<0.05) with cohesiveness (r=-0.51). Some FG containing 6.5 percent pork skin fractured (an indication of brittleness) and all FG containing 10 percent pork skin fractured. Less cohesive samples are usually more brittle.

Cohesiveness partly explains how skin, fat and AW levels affect the properties of fat emulsion gels. Although soluble collagen protein from pork skin can bind water and emulsify fat, too much soluble collagen causes fat emulsion gels to break down. Soluble collagen does not have the water-binding and fat-emulsification capacity of the salt-soluble meat proteins, myosin and actin. The lower cohesion values in FG with more pork skin and more soluble collagen were reflected in the emulsion stability test where FG with more than 5 to 6 percent pork skin were less functional.

Fat Emulsion Gel Incorporation

Bologna containing selected FG required more force to fracture and were harder (P<0.05) than control low-fat/high-added-water bologna but similar (P>0.05) to the full-fat control (Table 1), all desirable responses. Bologna containing FG were chewier than the full-fat control because they were more cohesive, and the bologna containing the "best emulsion stability" FG (FG released least amount of fluids during simulated cooking) was chewier than the low-fat/high-added-water control because they were harder. Sensory panelists found incorporating FG made the hardness of low-fat/high-added water bologna more like the full fat control, which supported objective texture measurements. Bologna containing the "most economical" (FG primarily fat, water and skin, all inexpensive ingredients) or "best hydration" (FG held the most water) FG had more (P<0.05) resistance to bite and was more springy than the low-fat/high-added-water control, but similar to the full-fat control. As previously mentioned, low-fat/high-added-water bologna is often softer than full-fat bologna (as was the case in this study), and adding FG to low-fat/high-added water bologna made the hardness much more like that of a full-fat bologna.

Incorporation of FG in bologna did not alter (P>0.05) sensory panel juiciness scores of low-fat/high-added-water bologna. The bologna made with the "best emulsion stability" FG provided a more "coated" mouth feel than the bologna made with the "most economical" FG.

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Table 1. **Least square means for texture profile analysis attributes, Lee-Kramer shear and taste panel scores for bologna manufactured with or without pork skin, fat emulsion gels.**

	Best emulsion stability[x]	Best hydration[y]	Most economical[z]	10% fat/ 30% AW	30% fat/ 10% AW	OC[d]
Compression						
Fracturability (N/g)	19.52	21.44	20.13	17.45	19.68	❖
Hardness (N/g)	29.28	27.46	26.48	24.42	27.50	❖
Cohesiveness	0.19^{b}	0.20^{b}	0.19^{b}	0.20^{b}	0.13^{a}	⌘
Springiness (mm)	5.91^{a}	5.80^{a}	5.75^{a}	5.71^{a}	6.54b	⌘
Gumminess (N/g)	5.67^{b}	5.48^{b}	5.04^{b}	4.88^{b}	3.68^{a}	⌘
Chewiness (J/g)	0.033^{c}	0.032^{bc}	0.029^{b}	0.028^{ab}	0.024^{a}	⌘
Kramer shear						
Peak force (N/g)	16.90	17.06	17.45	17.52	19.08	⌘
Energy (J/g)	0.109^{a}	0.112^{a}	0.113^{ab}	0.121^{bc}	0.127^{c}	⌘❖
Panel texture[f]						
Resistance to bite[g]	6.94^{a}	10.05^{b}	9.74^{b}	6.87^{a}	8.59^{b}	❖
Springiness[g]	6.38^{a}	9.54^{c}	8.92^{bc}	6.92^{a}	7.70^{ab}	❖
Cohesiveness[g]	8.66	7.97	8.18	8.05	9.89	⌘
Adhesiveness[g]	7.28^{b}	6.87^{ab}	5.62^{a}	6.62^{ab}	8.34^{c}	⌘
Panel flavor[f]						
Juiciness[h]	8.60^{b}	8.59^{b}	8.98^{b}	8.77^{b}	7.05^{a}	⌘
Bologna flavor[g]	8.93	9.07	9.26	9.33	8.88	
Saltiness[g]	7.28	7.18	7.63	7.19	7.13	
Panel aftertaste/feel[f]						
Bologna flavor[g]	7.47	8.07	8.49	7.99	8.13	
Mouthcoat[i]	7.41^{b}	6.72^{ab}	5.92^{a}	6.77^{ab}	8.79^{b}	⌘

⌘The average of the three bolognamade with a fat emulsion vs. the high fat control; $P<0.05$.
❖The average of the three bologna made with a fat emulsion versus the low-fat, high-added-water control; $P<0.05$.
[abc]Means in the same row having different superscripts are significantly different ($P<0.05$).
[d]OC = orthogonal contrasts.
[f]All attributes rated on a 15 cm scale.
[g]1=lacking; 15=intense.
[h]1=dry; 15=moist.
[i]1=clean; 15=coated.
[x]10% fat/30% AW bologna + best emulsion stability fat emulsion gel.
[y]10% fat/30% AW bologna + best hydration fat emulsion gel.
[z]10% fat/30% AW bologna + most economical fat emulsion gel.

Table 2. **Least square means for objective and sensory appearance measurements of bologna manufactured with or without pork skin, fat emulsion gels.**

	Best emulsion stability[x]	Best hydration[y]	Most economical[z]	10% fat/ 30% AW	10% fat/ 10% AW	OC[e]
L*	74.40^{c}	71.67^{b}	71.44^{ab}	69.77^{a}	73.94^{c}	⌘❖
a*	16.77^{a}	18.42^{b}	18.41^{b}	18.50^{b}	17.01^{a}	⌘❖
b*	14.97^{a}	15.15^{a}	14.93^{a}	15.16^{a}	15.64^{b}	⌘
Cured meat color	1.75^{a}	1.89^{b}	1.90^{b}	1.92^{b}	1.75^{a}	⌘❖
a/b	2.49^{a}	2.73^{b}	2.76^{b}	2.74^{b}	2.43^{a}	⌘
Panel appearance[h]						
Color intensity[i]	5.57^{b}	7.36^{c}	8.45^{cd}	9.03^{d}	2.40^{a}	⌘❖
Color uniformity[j]	9.37	9.39	8.46	9.35	8.72	⌘❖

⌘The average of the three bologna made with a fat emulsion vs. the high fat control; $P<0.05$.
❖The average of the three bologna made with a fat emulsion versus the low-fat, high-added-water control; $P<0.05$.
[abcd]Means in the same row having different superscripts are significantly different ($P<0.05$)
[e]OC=orthogonal contrasts.
[h]All attributes rated on a 15 cm scale.
[i]1=pale; 15=dark.
[j]1=uneven; 15=even.
[x]10% fat/30% AW bologna + best emulsion stability fat emulsion gel.
[y]10% fat/30% AW bologna + best hydration fat emulsion gel.
[z]10% fat/30% AW bologna + most economical fat emulsion gel.

However, FG incorporation was unable ($P>0.05$) to provide the same "coated" mouth feel associated with a full-fat bologna (Table 1).

Sensory panels found the average color intensity of low-fat/high-added-water bologna with FG was lighter ($P<0.05$) than the low-fat/high-added-water control, but not as light ($P<0.05$) as the full-fat control (Table 2). L* values (lightness) followed a similar pattern. The bologna containing the "best emulsion stability" FG was similar ($P>0.05$) to the full-fat control for all color measurements except b* values (yellow/blue). Incorporating the "best emulsion stability" FG into a low-fat/high-added-water bologna resulted in a bologna that looked very similar to a full-fat pork bologna.

Addition of FG to bologna had similar cook yield, purge and emulsion stability properties when compared to the low-fat/high-added-water control (Table 3). However, there was a trend ($P=0.08$) for the low-fat/high-added-water control to have poorer emulsion stability than bologna containing FG, which may indicate incorporation of FG into comminuted meats at higher levels could provide processing yield advantages.

Conclusions

Pork skin and reduced-lean pork trimmings have low economic value. They were successfully incorporated into low-fat meat products by creating a fat emulsion gel. The textural and functional properties of FG were characterized over a range of fat and AW levels and functional properties of FG for use as a raw material were optimized using 6 percent pork skin. Higher levels of pork skin resulted in FG that were less cohesive, perhaps because soluble collagen levels were too high.

Use of FG as a raw material improved texture and color by decreasing the softness and darkness associated with low-fat/high-added-water bologna. Low-fat/high-added-water bologna made with FG was more like

Table 3. Least square means for processing yields and raw bologna batter characteristics of bologna manufactured with or without pork skin, fat emulsion gels.

	Best emulsion stability[g]	Best hydration[h]	Most economical[i]	10% fat/ 30% AW	30% fat/ 10% AW	OC[e]
Cook yield (%)	89.47[a]	90.27[a]	90.20[a]	90.00[a]	94.49[b]	⌘
Chill yield (%)	87.77[a]	88.17[a]	88.23[a]	87.87[a]	91.67[b]	⌘
Purge (%)	2.35[b]	2.36[b]	2.47[b]	2.55[b]	0.92[b]	⌘
Emulsion stability						
Total fluids (ml/100g)	0.17	0.14	O.31	0.58	0.20	❖=.08
Fat (ml/100g)	0.00	0.01	0.00	0.03	0.01	
Gel water (m/100g)	0.17	0.13	0.31	0.55	0.19	❖=.08

⌘The average of the three bologna made with a fat emulsion vs. the high-fat control; P<0.05.
❖The average of the three bologna made with a fat emulsion versus the low-fat/high-added-water control; P<0.05.
[ab]Means in the same column having different superscripts are significantly different (P<0.05).
[e]OC=orthogonal contrasts.
[g]10% fat/30% AW bologna + best emulsion stability fat emulsion gel.
[h]10% fat/30% AW bologna + best hydration fat emulsion gel.
[i]10% fat/30% AW bologna + most economical fat emulsion gel.

a full-fat pork bologna than the low-fat/high-added-water control bologna. Sensory panelists found bologna made with FG were firmer and lighter in color. The value of reduced-lean trimmings can be increased by incorporating pork skin fat emulsion gels into comminuted meat products.

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[1]Timothy D. Schnell is a graduate student and Roger W. Mandigo is a professor in the Department of Animal Science.