Fat Reduction in Comminuted Meat Systems

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Introduction

Processed meats encompass a variety of meat products including ground beef, fresh sausages (fresh breakfast sausage, fresh country-style pork sausage), uncooked smoked sausages (mettwurst, polish sausage), cooked smoked sausages (bologna, franks, wieners, hot dogs), dried sausages (hard salami, pepperoni, cervelat, mortadella, chorizos), luncheon meats, cooked hams and canned meats (Rust, 1977). Comminuted meat systems (bologna, frankfurters) represent a major portion of the total pounds of retail product produced in the U.S. These meat products are those in which leanness can be controlled by the processor (Shand and Schmidt, 1990).

During the past few years, there has been a growing concern over the consumption of fats and cholesterol in the U.S. population. According to a survey of 1000 California residents, only 22.7% of the respondents indicated that fat and cholesterol did not affect their decision to purchase luncheon/sliced meats (Schutz et al., 1988). Evidence suggests that eating too much fat, both saturated and unsaturated, may increase the chances of getting cancers of the colon, breast, prostate and endometrium. Reducing fat in the diet can help decrease the risk of cancer, heart attacks and strokes, and assist in weight control (NIH, 1984).

Most Americans consume too much fat, which accounts for about 40% of the calories in their diet. A National Academy of Sciences committee recommends that people eat no more than 30% of their daily calories from fat (NIH, 1984). Therefore, traditionally formulated processed meats do not fit well into this recommendation. In addition, they are not suitable for incorporation into nutritional meal plans prepared by dieticians even though these products are excellent sources of many other nutrients. If these guidelines were followed, consumers would significantly reduce their consumption of traditionally formulated processed meats and shift towards lower-fat meat items.

The meat industry has responded to some of these diet-health issues by producing leaner cuts of meat and some low-fat processed meats. However, despite these efforts there still is a lack of sausages that contain less than 15% fat. Fat reduction in processed meats is not a new concept. Cured ham products that are labeled as "95% fat-free" have been around for several years and have gained wide acceptance. Recently, the industry has introduced a 91% fat-free hamburger patty. However, there are very few low-fat, coarsely-textured, or finely-comminuted sausages because fat has an important impact on tenderness, juiciness, appearance and cost of these types of products (Decker et al., 1986; Hand et al., 1987; Lee et al., 1987; Rust and Olson, 1988; Sofos and Allen, 1977).

The objectives of this paper are to present a review of the processing, sensory and storage characteristics of low-fat comminuted cooked sausages. In addition, the most current research relative to what new technological approaches that have been investigated that may provide alternative processing procedures to improve product performance will be discussed.

Characteristics of Low-Fat Comminuted Meats

Texture

Rongey and Bratzler (1966) determined that low-fat (4.5% to 7.4%) bolognas were tougher than higher-fat (17.6% to 24%) bolognas. Others have confirmed these findings in low- vs high-fat beef/pork frankfurters (15% vs 30% fat, Decker et al., 1986; 17% vs 24.6% fat, Hand et al., 1987; 17% vs 31%, Lee et al., 1987) and in chicken frankfurters (18.9% vs 28.5% fat, Baker et al., 1969). Therefore, a difference in the fat content of 7% to 15% will result in a difference in sensory firmness.

In response to consumer demands for lower-fat processed meats and an American Meat Institute petition, the USDA has given processors greater flexibility in formulating reduced-fat hot dogs and other cooked sausages (Parker, 1988). According to the regulation change, processors are permitted to exchange fat for added water (AW = % moisture - 4*% meat protein) provided their total in the finished product does not exceed 40%, and the total fat does not exceed 30% (USDA, 1988).

With the advent of the "40% rule," fat reduction does not necessarily result in comminuted products that are less tender. Effects of substituting AW for fat on textural and sensory properties of bologna formulated to contain 30% fat-10% AW to 5% fat-35% AW have been investigated by Claus et al. (1989). Treatment combinations tested were selected based on Figure 1. In general, reducing the fat content while increasing the AW resulted in a decrease in firmness (Figure 2). However, upon closer examination, if one compares only those treatments where the total of fat and AW was the same (i.e. 40%), trading AW for fat was effective in maintaining

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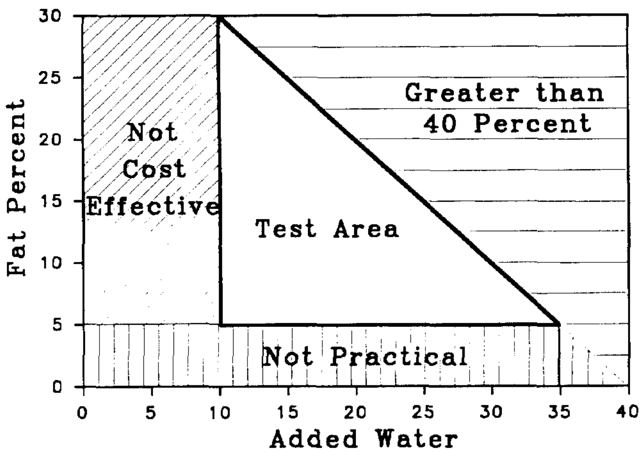
Figure 1

Test area for selecting various combinations of fat and added water that complies with the "40%" rule for comminuted meats.



products with similar firmness. When the total of fat plus AW equalled 40% the protein content was 11%, whereas a total of 30% corresponded to 13% protein. Therefore, the protein content played a major role in the firmness of the finished product. Instron texture profile analysis data followed a similar pattern as the sensory data, except that within a given protein level as the fat was decreased and the AW increased, resulted in a slight decrease in product hardness. Sensory springiness, firmness and cohesiveness increased as the protein content increased (Figure 2). Instron fracturability and hardness were affected more by AW than fat and were lower for the high-AW, low-protein bolognas.

The "40%" rule does permit processors the flexibility to modify the textural properties of comminuted meats formulated for lower fat levels. Predictive equations can be developed and used to formulate low-fat processed meats with similar firmness of high-fat processed meats based on specific combinations of fat and AW. To illustrate the utility of such regression equations, consider formulating a 10% fat bologna that is similar in firmness to a 30% fat, 10% AW bologna. Given the following equation (Claus et al., 1989), sensory firmness = 9.87-.0799(Fat)-.119(AW)-.00111 (Fat*AW), where Fat = 30 and AW = 10, sensory firmness equals 5.95. Using this value, and substituting a given level of fat (e.g. 10%) into this equation, results in an AW of 24.0% that is required to produce a low-fat product similar in firmness to a 30% fat bologna. These equations indicate that in order to achieve similar firmness of a high-fat product, the percentage increase in AW is less than the percentage decrease in fat. Replacement of fat by AW does not uniformly affect all processing, sensory and storage traits. In addition, the utility of these regression equations have some limitations as they are applicable to and influenced by the various factors involved in manufacture of a specific product. Some of the factors that affect the applicability of these equations include meat age, collagen content, smokehouse conditions (heating rate, humidity), type of product and product shape.

Juiciness

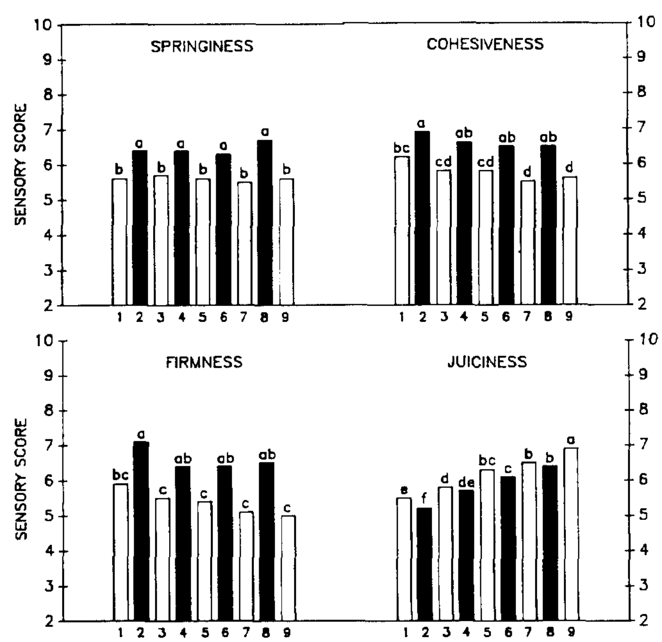
Juiciness is a significant palatability trait in processed meats. Fat reduction in comminuted products without concurrent increases in AW result in products that are drier (30% vs 17%, Decker et al. 1986; Hand et al. 1987, 24.6% vs 17%). Increasing the AW of a low-fat product (Figure 2) results in higher juiciness ratings (Claus et al., 1989). However, increasing the AW in low-fat processed meats may be at the expense of making the product too soft. Lee et al. (1987) made an important observation in that the desirability of juiciness was not necessarily associated with the highest juiciness scores. They investigated the effects of reducing the fat content from 31% to 20% in beef/pork frankfurters. The maximum desirability of juiciness was attained at fat levels of 20% to 27%. Juiciness desirability significantly declined at 31% fat despite increasing scores for intensity of juiciness.

Flavor

The flavor of meat products is influenced by the amount and type of fat (Baker et al., 1969). Even though processed meats such as frankfurters are highly seasoned, Carpenter et al. (1966) found that flavor was affected by the type of meat (beef, pork and lamb). Some of this difference may be attributed to differences in the melting characteristics of the

Figure 2

Treatment means for sensory panel traits of bologna.



Bars within same plot that have unlike letters are different ($P<0.05$). Numbers under bars in figure are treatments:

1 = 30%fat/10%AW	4 = 15%fat/15%AW	7 = 10%fat/30%AW
2 = 20%fat/10%AW	5 = 15%fat/25%AW	8 = 5%fat/25%AW
3 = 20%fat/20%AW	6 = 10%fat/20%AW	9 = 5%fat/35%AW

Figure from Claus et al. (1989)

fat. Rust and Olson (1988) indicated that when making a product with less fat and more water, it is important to remember that if the product is to have the same taste as products containing normal levels of fat, the level of spices and other flavorings will likely need to be changed. They stated that fat absorbs and masks some of the spice flavor; thus, as the fat level is reduced, different flavors in the formulation become much more pronounced. Wirth (1988) made a similar statement and suggested that it is possible to produce frankfurters with a minimum of 10% fat provided that in addition to a reduction in the seasoning, the salt content is reduced by 20% to 25%. In agreement with Wirth, sensory results of low-fat, high-moisture comminuted bolognas served at refrigerated temperatures were more salty than high-fat bolognas (Claus and Hunt, 1991). Others have shown that non-preblended, low-fat frankfurters containing 1.5% to 2.0% salt and served warm were less salty than high-fat frankfurters; however, when preblending was used, no difference in saltiness was observed (Hand et al., 1987).

Color

As the fat content of comminuted meats is reduced, Hunter "a" values (measure of redness) increase and "L" values decrease indicating a redder, darker product (Claus et al., 1989; Decker et al., 1986). The slightly darker color of the low-fat frankfurters might be remedied by adjusting the formulation to include more pork (Hand et al., 1987). Decker et al. (1986) reported that lowering the fat content from 30% to 15% in all-meat frankfurters resulted in an increase in the cured meat color. Increases in AW also affect meat color, however, not as much as fat reduction (Claus et al., 1989). Producing a redder, darker product may not be undesirable as consumers generally associate this appearance with leanness and as such may have a more positive nutritional image.

Cooking Properties

Cooking yields affect the cost to manufacture a processed meat, and also are important to control because changes in the cooking yields result in compositional changes in the finished product that may affect the palatability characteristics. Foegeding and Ramsey (1986) found that reducing the fat content in batters from 25.5% to 10% resulted in a significantly lower weight loss. Decreasing fat and increasing AW in bologna products results in greater cooking losses (Claus et al., 1989).

Storage Characteristics

Low-fat bologna stored in a refrigerated (3°C) display case for 14 days had a slightly more stable color than high-fat bologna (Claus and Hunt, 1991). Limited information is available on the stability of low-fat processed meats flavor with extended storage. However, one would anticipate that as a result of the reduction in fat there would be less unsaturated fat available to undergo oxidative changes. The effect of fat content on the antioxidative role of sodium nitrite has not been reported in low-fat, high-AW processed meats.

Purge accumulation in the packaged product during retail storage can detract from the marketability of any processed meat. As the fat content is reduced and the AW is increased in low-fat bologna, purge accumulation increases (Claus et al., 1989). Vacuum level imposed on the finished product during retail storage influences the amount of fluid accumulation. Rust and Olson (1988) normally recommend a high vacuum to maximize shelf life; however, if the product is not in a skin-tight package there is a constant pull on the product which will increase the amount of purge. Claus and Hunt (1991) studied the effects of two vacuum levels (low, 38.1 cm Hg; high, 66.0 cm Hg) on purge accumulation of low-fat, high-AW bologna. Purge accumulation was significantly greater for the product packaged in high vacuum (7%) than the low-vacuum (5.5%). In addition, 10% fat/30% AW bologna packaged in high vacuum had greater purge (10.1%) than 30% fat bologna (5.7%).

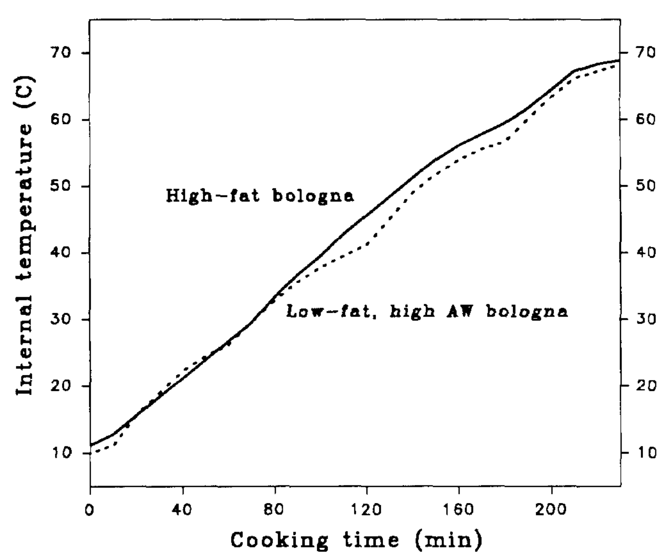
Aerobic and psychrotrophic counts of all-meat (30% and 15% fat) frankfurters formulated for less than 10% AW and stored for four weeks were not significantly different (Decker et al., 1986). However, our preliminary data (Figure 3) collected at VPI & SU indicates that under similar smokehouse conditions, high-fat bolognas have higher F-values (30.8) than 10% fat, high-AW bolognas (20.9). Therefore, reducing the fat content while increasing the AW may result in a shorter shelf life unless a higher temperature or additional cooking time is utilized.

Manufacturing Procedures

Water-binding and gelation characteristics are important in determining stability and texture of comminuted meat products (Comer, 1979). These functional properties can be affected by various manufacturing procedures. As the fat content of processed meats is gradually reduced while the water content is increased, the product's water-binding capacity will replace its fat-binding capacity as the critical issue

Figure 3

Internal temperature profile of low-fat and high-fat bolognas during heat processing.



in production (Rust and Olson, 1988). As a result of this "40%" rule for sausage products and the increased emphasis on fat reduction, there is a need for new and improved technologies in the manufacturing of sausages.

Several basic approaches can be used to successfully reduce the fat in processed meats. The first step with any method is the selection of leaner meats. The fat and caloric density also can be decreased by a "dilution effect" from substances like water and other low or non-caloric ingredients. The dilution effect by added water is only valid if the water is not lost during heat processing and subsequent chilling. In addition, dilution of the protein also would occur, contributing to a softer textured product (Claus et al., 1989). Meat proteins can absorb more water and become softer than desirable for optimum firmness (Comer et al., 1986). Batter formulations that have higher initial fat contents result in a greater decrease in fat percentage in the finished product as a result of incorporation of non-meat ingredients. However, the dilution effect is limited to an overall reduction in fat by 0.5% to 1.5%. Furthermore, depending on the choice of ingredients, this may not result in a significant reduction in total calories. Hull and Rogers (1991) replaced part of the fat with a carbohydrate source (beans or rice) in low-fat beef frankfurters. They found that frankfurters that contained 12.5% fat and formulated with 12.5% carbohydrate still contained more than 40% of the calories from fat. Frankfurters containing 5.7% fat and formulated with 25% carbohydrate did achieve NIH guidelines for calories from fat.

Prerigor Meat

Since low-fat, high-moisture comminuted meats are known to have lower cooking yields, greater purge accumulation and result in less firm products, utilization of prerigor or hot-processed meat would seem to be a logical manufacturing step. In hot-processed, prerigor meat, ATP separates the protein complex, actomyosin, into its constituents actin and myosin. In this state, which also characterizes the relaxed muscle and which continues to exist for some time after death of the animal, much of the water used in frankfurter manufacturing can be stored in the relatively large spaces between the loosely bound proteins (Wirth, 1987). In order to fully capitalize on the benefits of hot-boned meat for sausage, this meat must be processed within 4 hr of slaughter for beef and within 1 hr for pork (Wirth, 1987).

Muscles in the prerigor state have a higher water-holding capacity and greater emulsifying capacity than muscles in rigor, and thus produce a sausage with reduced moisture loss and less fat rendering when cooked. Hot-boned, preblended frankfurters have more extracted myosin heavy chains and actin from the myofibrillar protein fraction than cold-boned preblends. Salted,hot-boned preblends produced more cohesive and firmer frankfurters than cold-boned produced products (Choi et al., 1987).

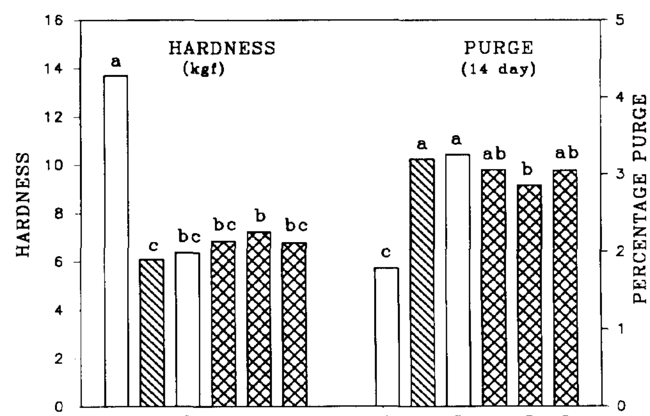
"Lite" frankfurters containing 22.5% fat and 17.5% AW produced from prerigor meat retained more water, were firmer and juicier than lite frankfurters produced using postrigor beef (Almeida and Rogers, 1991). However, prerigor-produced lite frankfurters were similar in yield, color, flavor, tenderness and shelf life.

Physical Manipulation

Massaging is a form of physical manipulation similar to mixing, in which a force is applied to the meat pieces and chucks during the curing operation. Mixing could be considered as the physical action necessary to incorporate added ingredients and assist in the process of extracting the myofibrillar proteins. In some respects, mixing time beyond that necessary to achieve these functions could be considered massaging. Massaging assists in improving the extraction of surface proteins that are vital in the development of adequate bind between meat pieces in restructured meat products upon heat processing. In addition, massaging facilitates moisture retention within the muscle chunks. In the case of sausage manufacture, Claus et al. (1990) investigated the effects of massaging on the sensory and storage properties of 10% fat, 30% AW bologna. The initial processing of all formulations prior to the massaging treatments involved mixing the lean ground meats with salt, enough water to provide a 5% brine strength, and cure ingredients for 2 min. Massaging was done for 5 hr with a continuous cycle of 10 min on and 20 min off. No improvement in bind (Instron hardness, cohesiveness, tensile break force) or reduction of cooking loss was measured as a result of massaging (Figure 4). The effects of ionic strength were determined by controlling the amount of water added to the meat mix during massaging. Purge accumulation in the package among the low-fat treatments was slightly reduced only by massaging with all of the formulation water and none of the fat (Figure 4). Although some improvement in purge reduction was noted, significant improvements in cooking yields, texture and storage properties were not achieved. Lower water-holding ca-

Figure 4

Treatment means of bologna hardness (Instron texture profile analysis) and purge accumulation as affected by massaging, preblending, and controlled water addition.



Bars within the same plot that have unlike letters are different ($P<0.05$). Treatment number under bars:
1 = control (30% fat) 4 = massaged with 50% water, 0% fat
2 = one day process 5 = massaged with 100% water, 0% fat
3 = preblended 6 = massaged with 100% water and fat
2-9 = 10% fat/30% added water

Adapted from Claus et al. (1990).

pacity in the low-fat, high-added water treatments may be related to the lower ionic strength compared to the control containing 10% AW. Another explanation offered by Claus et al. (1990) for not attaining significant improvements in bind and reduction of cooking losses or purge accumulation may have been the physical disruption of the massaged preblend as a result of mincing through a 1.4 mm plate.

Increasing massaging or tumbling time in the manufacture of restructured products is known to have beneficial effects. Ockerman and Wu (1990) determined the effects of tumbling hot-boned, ground pork prior to chopping on the acceptability of emulsion-type sausage (25% fat). Salted, cured, seasoned ground pork was placed in plastic bag and tumbled (10 min/hr) for up to 24 hr. Unlike the responses found in restructured products, they found no difference in cook yield between 0 hr tumbling and 12 hr tumbling. In addition, 0 hr tumbling had higher cook yields than 24 hr tumbling. Hedonic sensory results indicated that tumbling time prior to chopping had no significant effect on tenderness or cohesiveness.

Non-Meat Ingredients

Various non-meat ingredients have been tested to improve the processing, sensory and storage characteristics of low-fat comminuted processed meats. Park et al. (1990) investigated the effects of elevated levels of water and oleic acid on consumer preferences of low-fat frankfurters. Frankfurters formulated to contain 14% to 16% fat, maximum AW and high-oleic sunflower oil as the primary fat source were equal to or superior in aroma, flavor, texture and juiciness to the 28% fat control frankfurters.

Decker et al. (1986) reported that using leaner meats to reduce the fat content from 30% to 15% in all-meat frankfurters containing less than 10% AW caused the products to become tougher in texture. Replacement of 20% or more of the meat with hydrated isolated soy protein in the 15% fat products reversed the negative effects of using leaner meats; however, high levels of hydrated protein resulted in a more pronounced soy flavor.

The effects of various starches and gums in meat batters have been previously summarized (Shand and Schmidt, 1990). Most of these ingredients have been evaluated in meat batters containing more than 20% fat and non-elevated AW levels. In general, starches (potato, wheat, corn) improved batter stability and product firmness. The major contributions of gums (carrageenan, gum arabic, locust bean gum, xanthan) in low-fat comminuted meats include the modification of water binding, emulsion stability and product firmness.

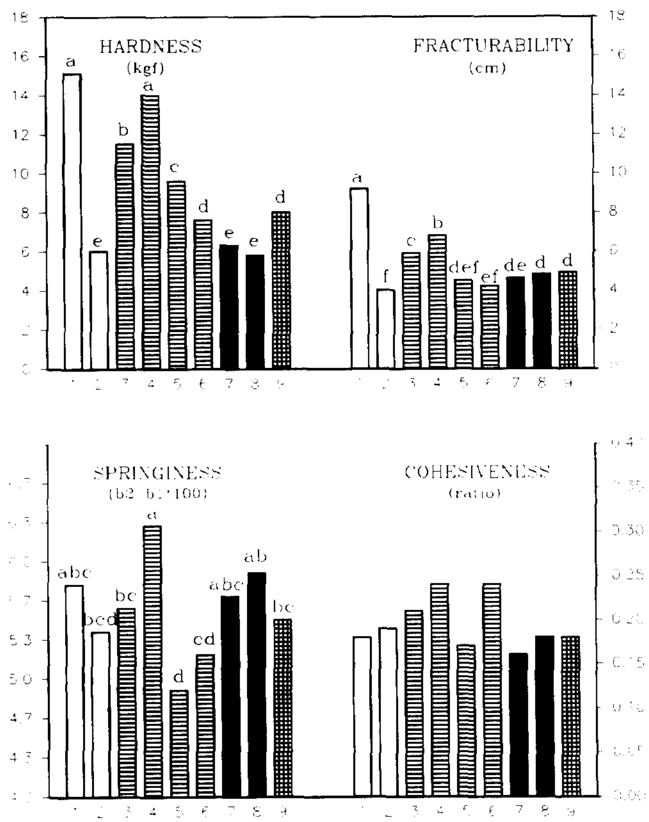
Dietary fibers and other selected starches have been studied in low-fat, high-AW comminuted meat systems (Claus and Hunt, 1991). Incorporation of dietary fibers (DuoFiber®, sugar beet pulp fiber; Nutrio-P Fibre 150M, pea fiber; Better Basics™ 780 oat fiber;) were more effective than starches (Firm-tex®, starch; wheat starch) in increasing the firmness of low-fat bologna (Figure 5). Bolognas formulated with DuoFiber were most similar to high-fat bolognas in firmness, but judged as less desirable in flavor. Another problem with the incorporation of certain dietary fibers was a noticeable increase in graininess. Decreasing particle size of the dietary fiber may decrease graininess; however, reduction in particle size is known to decrease water-holding capacity. Purge accumulation can be decreased by addition of various dietary fibers (Duofiber®, Oat fiber) and starches, particularly Firm-tex® (Claus and Hunt, 1991).

Conclusion

Statistical models have been developed that enable processors the ability to predict the consequence of formulating a low-fat product with different combinations of fat and AW on a given trait. However, these models are very limited in their application in that optimizing on one trait, such as product firmness, often is at the expense of several other processing, sensory and storage characteristics. Therefore, a concerted

Figure 5

Means for Instron texture profile analysis of low-fat bologna containing texturizing ingredients.



Springiness: b_2/b_1*100 = Base width of second compression/base width of first compression × 100. Cohesiveness: A2/A1 where A2 = area under the curve of first compression and A1 = area under the curve of the second compression. Bars with different superscript letter are different ($P<0.05$).

Treatment number under bars:

1 = 30% fat/10% added water	6 = Pea fiber 3.5%
2 = 10% fat, no added ingredients	7 = Wheat starch 3.5%
3 = DuoFiber 3.5%	8 = Firm-tex starch 3.5%
4 = DuoFiber 5%	9 = Isolated soy protein 2.0%
5 = Oat fiber 3.5%	2-9 = 10% fat/30% added water

Adapted from Claus and Hunt (1991)

effort needs to be made to build models that can be integrated together that take into effect all of the commercially important traits of low-fat cooked comminuted sausages. Substituting AW for fat is effective in preventing some of the undesirable changes associated with fat reduction. Without this added flexibility provided by the new ruling, the reduction of fat in processed meats would result in products that are tougher, more rubbery, less juicy and more expensive than high-fat products. Addition of non-meat ingredients appears to have the greatest effect on the processing, sensory and storage characteristics of low-fat comminuted sausages. However, other areas involving collagen, processing procedures, thermal processing and gelation characteristics need to be explored further in low-fat, comminuted meat systems.

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Discussion

E. Mills: Jim, do you have any explanation for the increased saltiness of those low-fat products?

J. Claus: I think what happened in the products that I worked on, it was also an elevated moisture content. And so with that elevated moisture content, the salt is more soluble than in high-fat, non-added water product. And so it was easier for the panelists to perceive the saltiness.

Mills: Have you had an opportunity to make any measures of brine strength or actual salt content in the water in those products? When you are adding a lot more water, you are reducing the effect of salt concentration of the water that's there. We've observed the same thing. It's been real interesting to me that it's happening. But I'm not quite ready to explain it.

Claus: Yes. We have not measured the brine strength and I'm sure that is something that needs to be looked at. I may not have emphasized it enough, that by altering the fat content, and of course the other speakers have addressed this, you certainly affect the flavor of the product and that's even in these seasoned products.

P. Sleper: Jim, I have a couple of questions for you. Referring back to the shelf life issue, where you said the higher water products may have a shorter shelf life, are you talking about a bacterial standpoint or organoleptic?

Claus: Pam, that was a good question. What I was referring to is, from a microbiological standpoint, if we look at the internal temperature profile of comparing a low-fat, high-moisture product to a high-fat product. In order to get the same "bacterial shelf life," if you're using a standard cooking cycle, you would most likely have to increase the cooking time or increase the internal temperature that it's going to.

Sleper: And the next question is, on these high-moisture products, your one slide showed that you have more purge and more cooking loss. Do you have any idea of your overall nutritional values, how they compare of the end products, high-fat formulation versus lower-fat formulation? And that may also go back to the question about the salt perception, when you're cooking out more water, how are your sodium values in the end product, which is what you're actually tasting in the sensory evaluation?

Claus: OK. As far as the chemical analysis on sodium, that was something that we did not do and the caloric content etc., of the finished products. However, the chemical analyses for moisture, fat and protein were analyzed and tabulated and we were basically very effective in achieving our goals for the fat and added water that we wanted to within a percent or percent and a half. Now that's after the product has been cooked and thoroughly chilled. What we haven't accounted for is that extra moisture loss and how that affects the compositional effects of what remains in the product.

Sleper: So in an end product then, what kind of percent fat reduction did you achieve? In your formulation, if I understand, you had 30% versus 10%, but in the actual finished product as a consumer would eat it, what kind of fat reduction did you have?

Claus: OK. When we formulated for 10% fat, 30% added water, we were approximately 9 to 9.2 on the fat, chemical fat that the finished product had, and in added water there was a little bit above the 30%. In all of the products that we formulated, we were at or below the 40% rule.

B. Smith: When you were evaluating the bind with the Instron machine, was the emulsion placed in a mold, or how did you get the particular shape in the product?

Claus: The doughnut-shaped product? Is that what you're talking about, tensile test?

Smith: Yes.

Claus: We had a device that was made through the machine shop, basically a cookie cutter, if you will, so that once a product was cooked, we slice it to a particular thickness and then use that device to cut that shape out. The reason why we did that was that we had looked at using the pneumatic jaws on an Instron, if you are familiar with that, and some of the problems with that type of approach is that it either crushes the product that you're trying to evaluate or it slips if you don't have enough air pressure. The other approach that we also looked at before we got to this was to mount some pins on the pneumatic jaws that were set at a depth that wouldn't crush the product. But then you get some shearing from the pins on that apparatus. This one seemed to be the most effective at really getting at the bind of that particular product.

Smith: So the entire doughnut shape before you sliced it was taken out of the normal round log?

Claus: Exactly. Out of the center.