PROPERTIES OF LOW-FAT, HIGH ADDED-WATER BEEF SAUSAGES CONTAINING PHOSPHATED STARCHES

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SUMMARY

Phosphate modified starches increased sausage yield more than native starch, but added water from increased yield also softened texture. Sausages with potato or wheat starch had higher yields than those with corn or waxy maize starch. Sausages with modified potato starch had the highest yield although the retained water had a softening effect on texture. Ranking the starches from highest to lowest based on a combination of traits was: potato, wheat, corn, and waxy maize. The phosphate modification did not seem to increase starch-meat interactions as indicated by differences in force and texture measurements. However, the increased water retention may have obscured texture differences. Endpoint temperature affected texture more than yield. In conclusion, phosphate-modified starches increased sausage yield and decreased firmness more than native starches.

INTRODUCTION

Non-meat ingredients have been used in meat products for centuries. Because starches bind water, they have become important in the production of sausages with higher added water. Many modified starches are commercially available for food use. However, many of the types and degrees of modification are proprietary. Therefore, little is known about why some starches work better than others, and decisions based on chemical modifications are difficult to make. Lim and Seib (1993a) described procedures for chemical substitution of phosphate groups in starch. The objective of this study was to determine the effects of phosphate (monoesters) substituted starches on water holding capacity and texture of low-fat, high added-water sausages made in a model batter system. Sausages were processed to two endpoint temperatures to determine if the starches behaved differently with greater gelatinization.

MATERIALS AND METHODS

Starch Modification and Characterization

Corn, waxy maize, potato, and wheat starches were phosphorylated at pH 8.0 to form monoesters (Lim and Seib, 1993a,b). To verify that starches were modified, phosphorus and the degree of phosphorus substitution was determined. Rapid visco analysis was conducted to determine pasting temperature, peak viscosity, temperature at peak viscosity, breakdown, and setback. Gelatinization temperature was determined by DSC.

Product Formulation and Manufacture

Batter sausages were formulated from beef quadriceps and subcutaneous fat to contain 5% fat, 35% added water, and 3.5% starch. The control formulation contained 0.5% phosphate and no starch. Batches (1.37 kg) of meat and ingredients were mixed and passed once through a 1.4 mm plate in a Griffith GL-86 Mince Master. Product was stuffed into 50 mL disposable polypropylene tubes and cooked in a water bath to an internal endpoint of either 70 or 80°C. Water temperature was incrementally increased to simulate smokehouse cooking. After cooking, the tubes were cooled in water (17-19°C) for 15 min.

Processing Yields, pH and Proximate Analysis

Cooking losses were determined on sausages using the following equation: [(Raw weight-Cooked weight)/raw weight]×100. Reheat loss of sausages was determined as: [(Initial weight- Reheated weight)/Initial weight]×100. Raw or cooked batter (10 g) was blended with 40 mL distilled water and the pH measured. Sausages cooked to 70°C were analyzed for moisture, fat, and protein.

Texture Analyses

Lee-Kramer peak shear force per unit weight was determined by taking a 6 cm long section of each sausage and cutting it longitudinally into halves which were placed cut side down and perpendicular to the slots in the test cell. Texture profile analysis was determined by compressing 1.9 cm-high samples to 75% of their original height. Results were expressed as: hardness, cohesiveness, springiness, gumminess, and chewiness (Bourne, 1978).

Statistical Analysis

Starch data were analyzed as a completely randomized design and sausage data (three replications) as a split-plot with formulation being the whole plot and temperature the sub-plot using SAS General Linear Models procedures and least squares means separation techniques.

Results and Discussion

Starch Characterization

Starch modification reduced the gelatinization temperature (Table 1; P<0.05) and increased two to ten times the degree of phosphate substitution of all starch sources. Starch modification reduced pasting temperatures and changed several physical properties of the four starches. Thus, modification of starches was effective.

Potato starch had the highest degree of phosphate substitution and greatest decrease (10°C) in gelatinization temperature compared to the native starch (Table 1). Modified corn, waxy maize, and wheat starches also had lower gelatinization temperatures than their native counterparts (6.6, 4.2, and 4.0°C, respectively). Pasting temperature curves (data not shown) were different for each native starch compared to its modified counterpart. Rapid visco analysis revealed that starch phosphorylation increased peak, breakdown and setback viscosities, and decreased the temperature of pasting onset and temperature at peak viscosity for all starches.

ph and Proximate Composition

Raw batters containing starch had a pH of 5.75±.02 while the control batter pH was 6.07±.02. Differences between the control and starch-containing batters were due to the alkalinity of the phosphate used in the controls. Batter and raw material temperatures never exceeded 5°C during processing. Moisture in sausages formulated with different starches varied from 74.1 to 78.3%. Control sausages and those with modified potato starch retained the most water, and sausages with native corn and waxy maize starches retained the least (Table 2). In general, sausages with modified starches retained more water than their native counterparts. As expected, percentage protein was inversely related to moisture. These differences were most likely due to differences in yields. Fat did not differ (P>0.05) between sausages. Sausages were successfully formulated to 5% fat, although the amount of added water varied considerably. Differences in added water were expected and reflect the ability of different starches to retain water. Five formulations (modified potato, potato, control, modified wheat, and wheat starch) exceeded 30% added water. Native corn and waxy maize, and modified corn and waxy maize retained the least added water (P<0.05). Only modified potato starch succeeded in maximizing added water and actually exceeded USDA's 40% rule by almost 2%. Three others (potato, 38.9; control, 38.3; modified wheat, 37.0) might have the ability to reach the 40% rule without the aid of other processing ingredients.

Processing yields

Starch source interacted ($P<0.05$) with endpoint temperature for cooking loss. Within a temperature, sausages containing phosphate-modified starches had lower cooking losses (Table 2; $P<0.05$) at both temperatures than their native counterparts. Sausage with potato starches had the lowest cooking losses of any starch source, and those with modified potato starch had only 7.1% cooking loss. When cooked to 70°C, native and modified potato starches had cooking losses equal to or less than control sausages. With the exception of modified waxy maize and modified corn, cooking losses increased with the higher temperature and this effect on water holding capacity is evident when the controls (containing phosphate) are compared. Both modified corn starches had similar losses at both temperatures while their native counterparts had higher losses at 80 than at 70°C. This was likely caused by the decreased gelatinization temperature accompanying starch modification. Modified potato starch had the lowest ($P<0.05$) pasting (49.8°C) and gelatinization (49.2°C) temperatures of the starches tested which would allow it to function when other batter components would release water. Modified wheat starch followed closely behind potato and also had lower gelatinization (51.5°C) and pasting (62.7°C) temperatures than the corn and waxy maize starches. Generally, the lower the gelation temperature the higher the cook yields. However, native potato starch had gelatinization and pasting temperatures similar to the modified corn starches but still had lower cooking losses.

For reheating loss, a significant starch source by temperature interaction indicated that treatments cooked to 80°C lost less weight than those cooked to 70°C (Table 2). This would be expected since those cooked to 80°C had a harsher cooking process which resulted in higher cooking weight losses initially, so less moisture would be lost during reheating. Modification of starches did not affect ($P>0.05$) reheating loss; but all sausages containing starch had lower reheating losses than the control at both endpoint temperatures. Overall, those starch treatments with higher cooking losses had lower reheat losses, and vice-versa.

Measurements of Texture

A significant interaction of starch source and temperature occurred for Lee-Kramer peak force (Table 2). Control, corn, modified corn, and potato sausages cooked to 80°C had higher peak forces than those cooked to 70°C, with the control having the greatest force. Shear values were highly dependent on cooking loss since greater water loss resulted in a more dense, concentrated product. At 70°C there were no differences in shears while some differences occurred in sausages cooked to 80°C. When cooked to 80°C, modified starches tended to produce sausages with slightly lower peak forces than those with native starch, a result expected since the modified starches retained more water. Claus et al. (1989) also reported on the softening effect that water has on the processed meat system.

A significant temperature by starch source interaction existed for hardness. As with Lee-Kramer peak force, hardness of control and starch-containing sausages heated to 70°C were not different (Table 2; $P>0.05$). For those heated to 80°C, control sausages were hardest and sausages with modified waxy maize were softest. Control sausages and sausages containing native corn and wheat starches were harder when cooked to 80°C while sausages with native and modified waxy maize starches were harder at 70 than at 80°C. When sausages were cooked to 80°C those containing modified starches tended to be softer than those with native starches, but this trend was significant only for wheat starch.

Starch source and temperature significantly affected cohesiveness. Control and sausages containing corn, modified corn, and potato were the most cohesive while those containing waxy maize were the least (Table 2; $P<0.05$). Contrast testing indicated that starch modification did not affect cohesiveness. Sausages cooked to 80°C were less cohesive than those cooked to 70°C (data not shown). Again, sausages with waxy maize starch showed decreased texture, likely resulting from interruption of meat proteins during gelation.

Results for gumminess (data not shown) followed a pattern similar to cohesiveness. No differences ($P>0.05$) occurred for springiness (data not shown) for either starch source or endpoint temperature.

Significant differences occurred for chewiness due to starch source but not for endpoint temperature. Sausages with native and modified waxy maize starches were least chewy while the control, corn, modified corn, and potato starch sausages were most chewy (Table 2; $P<0.05$). Increased cooking loss of control and corn starches likely caused their greater chewiness. Contrasts indicated that sausages containing modified starches were not different in chewiness from those containing native starches.

GENERAL OBSERVATIONS AND CONCLUSIONS

Ideally, batter sausages should have low cooking and reheating losses; moderate to high firmness; moderate to high hardness, cohesiveness, gumminess, and chewiness; and have a smooth surfaced, even texture. Sausages with waxy maize starches were mealy, mushy sausages that lacked cohesion and visual appeal. Corn starches were categorized as low yielding, very firm textured sausages that were visually mediocre. Native and modified potato starches produced high yielding, smooth textured sausages that were soft in texture. Native and modified wheat starches produced products with acceptable appearance, slightly soft texture and moderately low cooking and reheating losses. Ranking the starches from highest to lowest based on the combination of the above characteristics results in: potato, wheat, corn, and waxy maize. Based on textural and shear data, the phosphate modification did not seem to increase starch-meat interactions. However, the increased water retention may have obscured texture differences. Endpoint temperature affected texture more than yield. The biggest obstacle to overcome is the softening effect that appears to be due to starch and added water.

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