Functional Properties of Soya Isolate, Potato Starch and Wheat Flour in British Sausages

P A Whitehead LRSC, M K Knight, BSc PhD, and J M Wood, BSc, PhD

Leatherhead Food Research Association, Leatherhead, United Kingdom.

SUMMARY

The functional properties of soya isolate, potato starch and wheat flour in British fresh sausages have been evaluated. These ingredients were substituted for rusk individually and in combination in a pork and beef sausage recipe in a statistically designed experiment. The sausage structures were examined by light microscopy. The cooking performance of the sausages was evaluated and the sensory characteristics assessed by a trained taste panel consisting of eleven assessors. Soya isolate was found to have a major effect on the cooking performance and texture of the sausages with potato starch and wheat flour having a much lesser effect. The report describes the sensory changes that occur upon addition of each ingredient and the changes are discussed in terms of the structures seen in the light microscope.

INTRODUCTION

Functional ingredients such as milk proteins, plant proteins and polysaccharides are often added to meat products to solve problems such as shrinkage and distortion during coking and to modify eating quality (Comer and Allan-Wojtas, 1988). Cost is a major factor influencing the use of non-meat ingredients, but there is an increasing awareness of the potential benefits of using functional ingredients to improve product quality (Andres, 1989). However, there is a general lack of knowledge of the specific role of functional proteins and polysaccharides in meat products.

The sensory characteristics of a range of British sausages have been documented by Jones, Dransfield, Crosland & Francombe (1989). This study mainly examined commercial sausages , without identifying either the method of preparation or the formulation. Observations of the appearance of the sausages led to the conclusion that the effects of comminution on eating quality could override those of formulation. This is to be expected since meat particle size is clearly an extremely important factor controlling the texture of all meat products. However, the influence of functional ingredients on product eating quality is less clear and has not been documented.

An understanding of the properties and interactions of meat and non-meat proteins and polysaccharides in products, and their effects on the aqueous and fat phases, should enable more careful selection of the ingredients for improving product quality.

The purpose of this study was to identify the effects of functional ingredients on the appearance, cooking performance and eating quality of British Fresh sausages. Before experimental work was begun, a survey was made of the usage of functional ingredients, among the Food RA Meat and Fish Products Panel Members, to ascertain the range of ingredients currently used in the industry. Three ingredients were selected for this study from the results of the survey and these were soya isolate, potato starch and wheat flour. These ingredients were substituted for rusk, individually and in combination in a pork and beef sausage recipe in a central composite statistically designed experiment.

MATERIAL AND METHODS

Ingredients

Pork shoulder (80% visual lean, VL), pork jowl (40 VL), pork rind (90 VL), beef flank (70VL) and beef clod fat (5 VL) were obtained fresh from a local abattoir 24-48 h post-mortem. The pork shoulder was minced through a 2.5 cm plate and the pork jowl diced into 2.5 cm cubes. The meats were vacuum-packaged and blast-frozen at -30°C and transferred to a freezer at -18°C until required. The meats were thawed at 2°C for 24 h before bowl chopping. The rind was steam-cooked for 30 min, cooled and minced through a 4 mm plate before use.

Pork mechanically recovered meat (MRM), 75 VL, was obtained frozen from Perimax Meat Co. Ltd.

Rusk (DYR medium grist) was obtained from RHM Ingredients Ltd.

Seasoning was obtained from Lucas Ingredients Ltd. and was Honey Roast Pork plain (No. 5091). The seasoning contained sodium chloride, sucrose, triphosphate, dextrose, sodium sulphite, wheatflour, spices, ascorbic acid and dried honey.

Soya isolate 500E was obtained from Protein Technologies International. Trident Emblem heat-treated wheat flour was from Jas Bowman & Son Ltd and Farina potato starch was from Tunnel Avebe Ltd. The approximate compositions of the ingredients is shown below:

Soya isolate	91.5% protein	5.5% moisture	3% sugars	
Potato starch	<0.1% protein	<21% moisture	78% starch	
Wheat flour	8-11% protein	15% moisture	72.5-73% starch	1-1.5% cereal gum

Sausage Manufacture

The recipe for the control sausage is shown in Table 1, which shows that the meat content was 51.1%. The water to rusk ratio was 2.1:1. The levels of addition of the three non-meat ingredients (soya isolate, wheat flour and potato starch) are listed in Table II. These levels were selected in view of the results of the survey of typical usage levels by the industry.

The chopping procedure for the sausages is illustrated in Fig. 1. Also indicated are the methods of addition of the non-meat ingredients. The ingredients were chopped in an Alexanderwerk 20-1 bowl cutter and filled into Devro 280 casings in a Handtmann VF10 vacuum filler. The sausages were blast frozen and stored at -18°C before use.

TABLE I
Control pork and beef sausage recipe

Ingredient	Amount (%)
Pork shoulder 80 VL	15.0
Pork jowl 40 VL	15.0
Beef flank 70 VL	7.0
Cooked rind 90 VL	4.0
Beef clod fat 5 VL	5.0
Pork MRM* (75 VL)	6.0
Seasoning	2.5
Water/ice (1:1)	31.0
Rusk	14.5
Total	100.0
Total meat content	51.1
Lean meat content	30.58
Fat content	20.52

VL - % visual lean
* estimated meat content 85%

TABLE II
Levels of non-meat ingredients

Ingredient	Level of addition %		
	Lowest value	Mid-value	Highest value
Soya isolate	0	2	4
Potato starch	0	2	4
Wheat flour	0	1	2

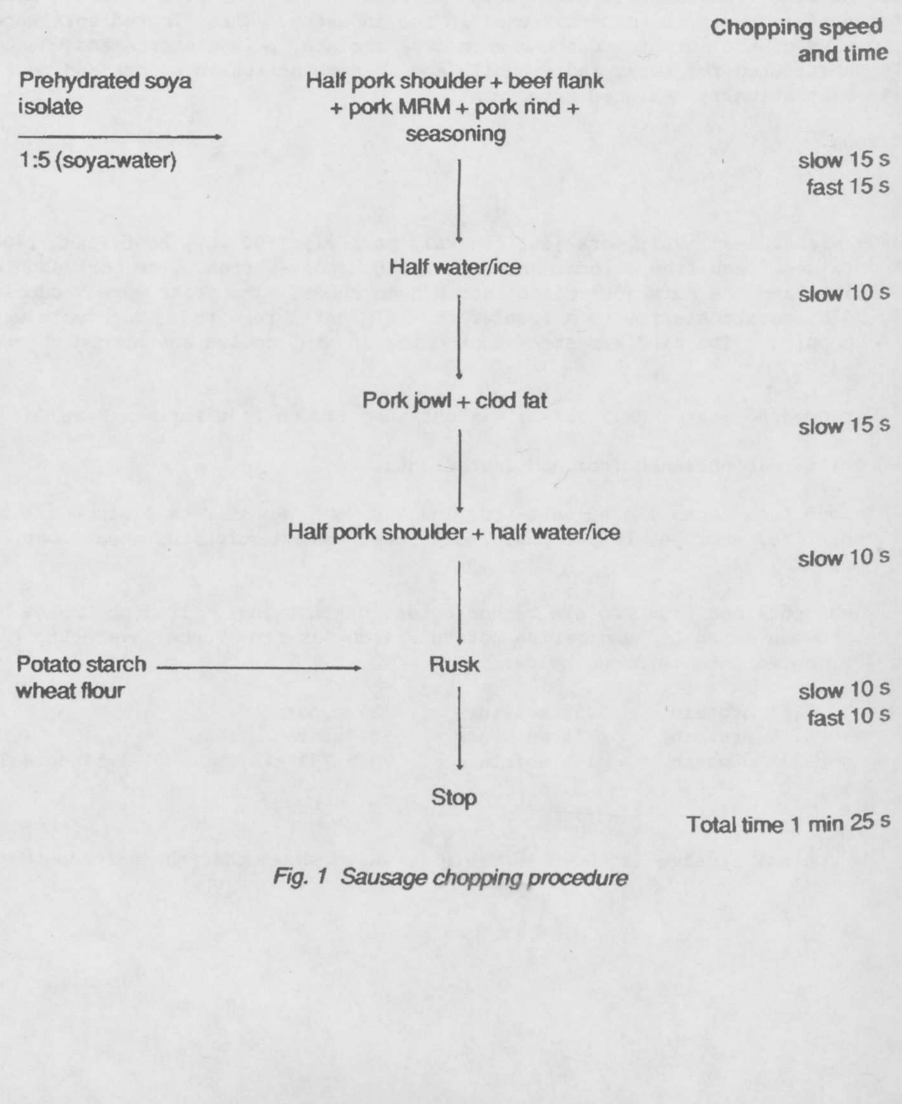

Fig. 1 Sausage chopping procedure

The levels of the non-meat ingredients for each batch of sausages prepared is shown in Table III

TABLE III
Non-meat ingredient levels in all sausages examined

Batch Code	Ingredient amount (%)*		
	Soya isolate	Potato starch	Wheat flour
A	0	0	2
B	4	0	0
C	0	4	0
D	4	4	2
E (control)	0	0	0
F	4	0	2
G	0	4	2
H	4	4	0
I	0	2	1
J	4	2	1
K	2	0	1
L	2	4	1
M	2	2	0
N	2	2	2
X	2	2	1

* added in replacement of part of the rusk

Sensory Analysis

Sample preparation

Sausages were cooked from frozen on a pre-heated electric grill for 30 min, being turned every 7.5 min. The cooked sausages were cut in half and served immediately to the sensory panel.

Sensory assessment

A panel of eleven experienced sensory assessors was used to evaluate the fifteen samples. Samples were evaluated in individual taste booths under artificial daylight illumination and at a controlled air temperature (21°C).

Derivation of terms

Several round-table discussion sessions were held to develop a vocabulary to describe important sensory characteristics of the samples. All samples were used for the derivation of terms. Textural characteristics were examined in the first few discussion sessions and then as the panel became more familiar with the samples they were able to examine appearance and flavour characteristics. In total, eighteen sensory attributes were derived (nine textural and nine flavour terms).

Training of panel

Fourteen training sessions were held. At each session panellists received three samples of sausages; samples G, N and H were used as training samples. The sensory characteristics (i.e. eighteen attributes) of the samples were scored using a 15 cm unstructured line scale on a form.

Profiling samples

Twenty-one profiling sessions were held over a period of six weeks. At each session panellists assessed two samples and the control sample X. This facilitated a comparison between all samples. Sample X was assessed twenty-one times whereas all other samples were assessed in triplicate.

Microscopy

Slices of raw and cooked sausages were frozen in liquid nitrogen and frozen sections cut at -25°C.

Cooking Losses

Cooking losses were determined on four sausages from each batch. The sausages were cooked from frozen by grilling under a pre-heated electric grill for 30 min, being turned every 7.5 min and cooled for 2 min before being weighed. The fat lost during cooking was collected and weighed and the water loss was calculated by difference. Observations were also made of the number and severity of splits in the sausages during cooking.

RESULTS AND DISCUSSION

Sensory Analysis

The sensory attributes, for which statistically significant differences ($p<0.05$) were found, related in general to the texture of the sausages, apart from meat flavour and pepper aftertaste. Attributes are listed in Table IV in decreasing order of the statistical significance of a simple comparison of all treatments by ANOVA. Differences between sausages were found in nine of the eighteen attributes. The attributes for which no statistically significant differences were found related in general to the flavour and aftertaste, apart from bready texture and coarseness of texture.

TABLE IV
Sensory attributes that showed significant differences between sausages

Attributes	Significance level
Stickiness	*** ($p<0.001$)
Greasiness	** ($p<0.01$)
Softness	**
Meat flavour	**
Toughness of skin	**
Moistness	* ($p<0.05$)
Chewiness	*
Pepper aftertaste	*

The attributes listed in Table IV were analysed further using multiple linear regression to determine trends in sensory properties due to the soya isolate, potato starch and wheat flour.

The relative importance of the linear, quadratic and interactive estimates for the sensory attributes are summarised in Table V. This table can be used as a guide to trends in the performance of the three ingredients. Significant linear terms indicate that a linear relationship exists between the parameter in question and the sensory attribute. Significant quadratic terms (I^2, S^2 and F^2) suggest that the relationships between ingredient level and sensory response is curvilinear. Significant interaction terms (IS, IF and SF) indicate that the relationship between the response and one of the two factors involved in the interaction is dependent upon the level of the other factor.

TABLE V
Relative importance of the parameter estimates for sensory attributes

Sensory attribute	Linear			Quadratic			Interaction		
	I	S	F	I^2	S^2	F^2	IS	IF	SF
Stickiness	↓**	↓**	-	-	-	-	-	*	-
Greasiness	↓**	↓***	-	-	-	-	**	-	-
Softness	↓**	↓*	-	-	-	*	-	-	**
Meat flavour	-	-	-	***	-	-	-	-	-
Toughness of skin	↑***	↑*	-	-	-	-	-	-	-
Moistness	↓*	-	-	-	-	-	-	***	-
Chewiness	↑***	-	-	-	***	-	-	-	-
Pepper aftertaste	-	-	-	**	-	*	-	-	-

I = soya isolate *** $p<0.001$
S = potato starch ** $p<0.01$
F = wheat flour * $p<0.05$
Arrows indicate increasing (↑) or decreasing (↓) relationship of sensory attribute

It can be seen from Table V that wheat flour had little effect on the sensory perception of the sausages. Potato starch mainly decreased the greasiness and, to a lesser extent, decreased the stickiness of the sausage. However, soya isolate had the greatest effect on the sensory characteristics. Increasing isolate levels reduced stickiness, greasiness and softness and increased the toughness of skin and chewiness of the sausages. Generally, soya isolate level influenced the textural characteristics of the sausages to a greater extent than the potato starch and wheat flour. Soya was the only ingredient to influence the meat flavour of the sausages.

In general, increases in either soya isolate or potato starch levels were linearly related to reduced stickiness and greasiness. There also appears to be an interaction between the soya and starch in relation to greasiness. Soya isolate was found to have a linear effect on softness. As the isolate level increased there was a general reduction in softness. The relationship between soya level and meat flavour produced a curvilinear response, with flavour scores lower at 2% soya compared with no soya, followed by increased flavour score at 4% soya. The isolate level also has an effect on the toughness of the sausage skins; as the isolate level increased the skins were perceived as being tougher.

The moistness of the sausages was affected by an interaction of wheat flour and soya isolate. Maximum and minimum values of moistness were recorded for 0 and 4% isolate, respectively, at the 2% wheat flour level. Sausages were perceived as being more chewy (i.e. more difficult to break down) as soya isolate levels increased. The peppery aftertaste perceived after swallowing was found to be greater for the mid-level of isolate (2%) than the lower and higher levels. The presence of gristle was perceived to be greater at the mid-level of starch (2%) than at the lower and higher levels of starch.

Cooking Losses

The total cooking losses for all of the batches ranged from about 16 to 23%. The data were treated by ANOVA and the results of this analysis are summarised in Table VI. Linear decreases in water, fat and total cooking losses were brought about by addition of soya isolate, and these cooking loss reductions were the most significant of all the results. Wheat flour caused a small increase in fat and total cooking losses. Interactions were identified between isolate and potato starch and isolate and wheat flour, and these mainly influenced water and total cooking losses.

TABLE VI
Statistical analysis of cooking loss results

Cooking	Linear			Quadratic			Interaction		
Loss	I	S	F	I^2	S^2	F^2	IS	IF	SF
Water	↓***						**	**	
Fat	↓***		↑**			*		*	
Total	↓***		↑*				**	**	

I - soya isolate *** $p < 0.001$
S - potato starch ** $p < 0.01$
F - wheat flour * $p < 0.05$
Arrows indicate increase or decrease in cooking loss, for linear relationship, in relation to control sample.

The cooking performance results showed a cluster of severe splitting effects in the mid-range of addition levels of soya isolate and potato starch. The amount and severity of splitting was lower at the extremities of addition levels of all three ingredients. No splits were observed in sausages containing 2% potato starch and 1% wheat flour.

Microscopy

A summary of the structures of selected sausage samples seen under the light microscope is presented below.

Control

Raw sausages mainly consisted of coarse rusk pieces with muscle and fatty tissue 'squeezed' between them. Some dispersed protein was seen and some free fat, which did not appear to be bound by protein but was bound by rusk. After cooking little network was present and the structure was very coarse. However, some protein was seen around and inside the rusk and this trapped some of the free fat.

4% soya isolate

More protein was visible in the raw sausage compared with the control sausage, and this was present both as spray-dried particles and as a dispersed network between the rusk and meat pieces. The soya spray-dried particles were seen inside muscle tissue as well as between particles of rusk, fat and muscle. Some evidence of a finer emulsion was seen in this sausage. The cooked sausage contained a continuous protein network trapping free fat and forming a continuous boundary around the rusk pieces.

4% potato starch

Little dispersed protein network was present in the raw sausage. Potato starch was visible as intact grains. Fat was mainly present in cells, but areas of free fat were visible along with fat trapped in a matrix in the cooked sausage. Upon cooking, the potato starch grains has swollen and to some extent joined together, but they were not generally continuous.

2% wheat flour

The raw sausage appeared similar to the control sample, consisting of intact rusk pieces, areas of muscle tissue and intact fat cells. Some dispersed network of mainly starch was also seen and the network contained isolated fat cells in both raw and cooked sausages.

4% soya isolate + 4% potato starch + 2% wheat flour

The raw sausages consisted of a considerable amount of dispersed protein with isolated fat cells trapped in the matrix. Some areas of fine emulsion structure were visible. The soya spray-dried particles were very evident, possibly more so than in the sausage containing 4% soya isolate, most likely indicating less hydration. In the cooked sausage, large areas of protein network were seen, trapping fat and starch. Fatty tissue, rusk and muscle were broken up by protein and the fatty tissue cell walls were broken down.

GENERAL DISCUSSION

The three functional ingredients were present in the raw sausages as either dispersed protein or starch and as intact particles. The soya, even though this was pre-hydrated, did not completely disperse from its particle structure. The potato starch was present as dispersed and intact grains and the wheat was present as a combination of rusk-like or cellular aggregates and simple grains. The functional ingredients tended to be found between the rusk, muscle and fatty tissue structures, except the soya, which was also found inside areas of muscle tissue. Soya appeared to behave differently from the other two ingredients in this respect. Soya has been shown by a gold-antibody-labelling-technique in other studies to be found in the muscle cells of finely comminuted products such as pâté (Groves, 1990). The soya appears as a banded structure following the repeating pattern of the sarcomere, inside muscle tissue. This ability of soya to bind to muscle may be related to its obvious functional effects in sausages identified in the present study. Where soya was present there was more of a connecting protein matrix and the rusk and fat components appeared to be surrounded by a protein layer.

Cooking highlighted structural differences seen between the ingredients, with increased protein dispersion seen in sausages containing soya, and fat coalescence occurring in sausages without soya. With soya, free fat tended to be trapped in the protein matrix. When potato starch was present with soya isolate, the soya protein particles appeared less hydrated, probably because of competition for water between the potato starch and soya. This effect was less noticeable with wheat flour present with soya. Potato starch also appeared to prevent meat protein dispersion, possible also by restricting the water available to hydrate the meat protein.

Soya particles when hydrated lost a certain amount of protein into the surrounding areas and heating increased this dispersion. The cooking loss results showed that soya had the most significant effect, causing a reduction in both water and fat losses. This observation is supported by the structural appearance of sausages containing soya, which consisted of a well-dispersed protein network. The less significant interactive effects of soya isolate and potato starch, and soya isolate and wheat flour on cooking losses (Table VI) are possibly due to the level of hydration of soya achieved in the presence of various amounts of the other ingredients.

The splitting of sausages during cooking was most severe at intermediate levels of addition of soya isolate and potato starch and no splits were observed in sausages containing 2% potato starch and 1% wheat flour. The reasons for the splitting effects are complex but are likely to be related to the state of water in the sausages (Barke,Maughan & Ranken, 1982).

The results of the sensory analysis show that the textural characteristics of sausages, like the cooking losses, are mainly influenced by soya isolate, but also to a lesser extent by potato starch. The levels of wheat flour used had little effect on the texture or flavour characteristics of sausages. High levels of soya produced a reduction in stickiness and softness, as well as causing an increase in chewiness and toughness of skin. These sensory characteristics are probably due to the ability of soya to absorb more water than the rusk it replaced in the recipe and to gel. In fresh sausage formulations the water-to-rusk ratio is usually about 2:1,whereas the water-to-soya ratio is usually about 4:1.

The control sausage used in this study had a water-to-rusk ratio of 2.1:1, whereas the sausage that contained 4% soya (batch B, Table III), had a water-to-rusk ratio 1.4:1, assuming a water-to-soya ratio of 4:1. Therefore, this reduction in water available to hydrate the rusk and meat protein (including the collagenous sausage skin), coupled with the presence of a greater proportion of a connecting protein matrix and reduced rusk content, appears to reduce the stickiness and softness and increase the chewiness and toughness of skin. Soya also reduced the greasiness of the sausages, a characteristic consistent with the presence of more finely emulsified fat.

Potato starch and wheat flour had much less effect on sensory characteristics than soya, but the high level of starch (4%) reduced stickiness.

Overall, it appears that the main trends observed related to the textural characteristics of the sausages, and soya isolate had the greatest effect on these trends. Starch levels had little effect on their own, but did have an interactive effect with isolate levels (i.e. the trend observed was dependent on the levels of both starch and soya). The state of soya hydration and its interaction with meat protein appeared to be important features of the structure of the sausages. Other structural considerations found to be important factors influencing the texture of sausages include - the extent of matrix present; the effect of protein surrounding the rusk pieces on their swelling during cooking; and the extent of protein dispersion to trap fat as a fine emulsion and to gel to provide a firmer texture.

The sausage formulation selected to assess the performance of the functional ingredients clearly has a significant effect on the results of this type of evaluation. It is not possible to generalise on the wide range of sausage formulations used in the UK; however it should be possible to generalise about the effects of functional ingredients in sausages. The trends identified in this study should therefore be relevant to most sausage formulations. The magnitude of the effects is likely to vary with factors such as lean meat, fat, water and rusk contents. In addition, the energy input into the chopping procedure will also affect the functionality of the ingredients. More energy is likely to increase the solubility of protein and starch. These aspects of sausage manufacture require further investigation.

CONCLUSIONS

1. Soya isolate had a major effect on the textural characteristics and also in reducing the cooking losses of pork and beef sausages, whereas potato starch and wheat flour showed much less effect.
2. As soya isolate level increased, the stickiness, softness and greasiness of the sausages were reduced and the chewiness and toughness of skin were increased.
3. The only effect of potato starch on the sensory properties of the sausages was to reduce their stickiness.
4. Wheat flour had little or no effect on the sensory characteristics of the sausages, although lower levels of wheat flour were examined compared with the levels of soya and potato starch in line with current industrial practice.
5. Structural features found to influence the coking performance and texture of the sausages were:

(i) the state of soya hydration and its interaction with meat protein;

(ii) the extent of continuous matrix present;

(iii) the extent of protein surrounding the rusk pieces and its effect on rusk swelling during cooking;

(iv) the extent of protein dispersion to trap fat as a fine emulsion and to provide a firmer texture by gelation.

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