The effect of inulin as a prebiotic fibre on organoleptic and technological properties of standard and low fat pork breakfast sausages

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***Abstract*—Along with the health benefits associated with prebiotic dietary fibres such as inulin this research was designed with the aim of developing healthier standard and reduced fat pork breakfast sausages. The objective was also to evaluate the effect of inulin on the sensory and technological properties (colour, texture, proximate analysis, fructan content, cookloss, emulsion stability and histology) of cooked sausages by comparing them with sausages prepared with the fat levels currently used by industry. Pork breakfast sausages were prepared at two fat levels (22% (standard) and 13% (reduced fat)) containing a prebiotic fibre (inulin) at four levels (0, 2.5, 5 and 7.5%). Inulin addition had no effect on overall acceptability, flavour or tenderness while the incorporation of inulin at 2.5% increased overall liking, juiciness liking and purchase intent. A low fat sausage containing 2.5% inulin had similar organoleptic properties to the standard sausage. The incorporation of inulin at levels of 5 and 7.5% reduced (P<0.001) emulsion stability of the pork sausages. Fructan analysis showed that the prebiotic fibre remained stable over a 14 day storage period and following cooking. An average energy reduction between standard and reduced fat breakfast sausages of 23% was achieved. It is possible to manufacture a standard pork sausage with up to 5% inulin in the final product without significant detrimental changes in the overall product quality. It is also feasible to produce an acceptable hypocalorific breakfast sausage with 39% less kcal/100g sausage enriched with 2.5% prebiotic fibre without sacrificing overall sensory and quality attributes.**

Keywords— **inulin, fat reduction, prebiotic fibre, sausages.**

I. INTRODUCTION

Growing awareness of the link between diet and health is fast changing consumer habits, so that there has been increasing demand for foods with health-enhancing properties. Inulin is a non-digestible oligosaccaride which is resistant to hydrolysis in both the stomach and small intestine and is considered to be beneficial to health as it is a known prebiotic fibre [1, 2]. The relationship between inulin and bifidobacteria results in the production of short-chain fatty acids, which creates a low-pH environment in the digestive system and helps with calcium and magnesium absorption This low-pH environment restricts the growth of disease-causing bacteria in the digestive system. Inulin is classed as a functional ingredient and is generally recognised as safe by the FDA. Many processed meat products have only minimum amounts of dietary fibre. Increased proportions of fibre in foods are known to reduce the risk of colon cancer, obesity and cardiovascular disease [3].

Meat products have great potential for delivering important nutrients into the diet and can be tailored to produce functional healthier products by adding ingredients considered beneficial for health or by reducing components such as fat. Epidemiological research has demonstrated a relationship between a diet containing an excess of energy dense foods rich in fat and an increased risk of obesity, certain cancers, high blood cholesterol and cardiovascular diseases [4] Fat is one of the main components of foods and contributes to their flavour, texture and appearance. Hence, fat reduction implies technological and commercial problems in the manufacture of emulsion type meat products such as breakfast sausages. Due to its structure, inulin is able to form a gel and for this reason it has excellent fat-like texture and is considered as a fat substitute in a wide range of foods.

The objective was also to evaluate the effect of inulin on the sensory and technological properties (pH, colour, texture, proximate analysis, fructan content, water holding capacity, emulsion stability and histology) of raw and cooked sausages by comparing

them with sausages prepared with the fat levels currently used by industry.

II. MATERIALS AND METHODS

A. Sample preparation

Pork breakfast sausages were prepared [5]. Following mincing, raw materials were assigned to one of eight treatments (Table 1): Inulin used was Fruitafit Tex® (Sensus, The Netherlands).

Table 1 Formulation for pork sausages containing inulin.

(%)	Pork	Fat	Ice	Rusk	Seas.	Salt	Inulin
T1	45	25	17.6	10.0	2	0.4	0.0
T2	45	25	17.6	7.5	2	0.4	2.5
T3	45	25	17.6	5.0	2	0.4	5.0
T4	45	25	17.6	2.5	2	0.4	7.5
T5	60	10	17.6	10.0	2	0.4	0.0
T6	60	10	17.6	7.5	2	0.4	2.5
T7	60	10	17.6	5.0	2	0.4	5.0
T8	60	10	17.6	2.5	2	0.4	7.5

B. Compositional analysis

The moisture, fat and protein content of the pork sausages was determined [5]. The total fructan content (expressed as g fructans/100g sausage) in the initial formulation and in the cooked sausage was measured using the Megazyme Fructan HK Assay kit (AOAC Method 999.03 and AACC Method 32.32; Megazyme International Ireland Ltd., Wicklow, Ireland). Total calories/energy value (EV) (kcal) per 100g samples were calculated using the Atwater values.

C. Emulsion stability

The emulsion stability of the sausage was determined [6].

D. Colour evaluation

Lightness (L^*), redness (a^*) and yellowness (b^*) values of raw sausages was measured by the CIE LAB system using a dual beam xenon flash spectrophotometer (Ultra Scan XE, Hunter lab, Virginia, USA).

G. Texture profile analysis

TPA was applied to the cooked pork sausages [7].

H. Sensory evaluation of cooked pork sausages

Eight different pork sausage formulations were evaluated by a 60 member untrained panel following 7 days of refrigerated storage (4°C). Pork sausages were cooked by grilling on a conventional oven at 180°C, turning every 3 min until cooked to an internal temperature of 71°C and held for a further 10 minutes to assist browning. Sausages were divided into 25 mm pieces, wrapped in aluminium foil and placed in a bain-marie (50°C) until serving (< 15 min). Samples were labelled with 3 digit random numbers and served in William Latin square order to panellists. Panellists were asked to evaluate overall liking, flavour liking, tenderness liking and juiciness liking on an eight point hedonic scale from extremely like (8) to extremely dislike (1).

I. Histology

Cooked pork sausages sections (20 mm) were frozen in isopentane cooled in liquid nitrogen. Samples were held at -25°C and sliced to 20 µm thickness in a cryostat (Leica 1950 Cryostat, Leica Microsystems AG, Wetzlar, Germany). Cryostat slices were stained with toluidine blue, air dried and examined with a Leica DMLB light microscope (Leica Microsystems AG, Wetzlar, Germany). For confocal scanning laser microscopy (CSLM) cryostat slices were stained with 0.05% aq Nile Blue and examined using CSLM (Carl Zeiss Ltd., Welwyn Garden City, Herts., United Kingdom).

I. Statistical analysis

Significance of differences among treatments at each day of storage were determined by analysis of variance (ANOVA) using the Least Square Difference method of GenStat (Release 10.1 Copyright 2007, Lawes Agricultural Trust, Rothamsted Experimental Station, Hertfordshire, UK). Differences were considered significant at the $P < 0.05$ level. Following rescaling, the effect of the panellists in the sensorial

responses was analysed by ANOVA according to a complete randomised block experimental design. The entire experiment was replicated three times.

Principal component analysis (PCA) using XLstat software was preformed on the correlation matrix of both the texture parameters and the standardised sensorial responses.

III. RESULTS AND DISCUSSION

The average fat content (Table 2) was 21.69 and 13.20% for standard and reduced fat cooked sausages respectively and represents an average reduction of 60% fat.

Table 2 Compositional analysis of cooked sausages

	%	% M	% Fat	% P	EV[3]	CL[4]	ES[5]
I[1]	0	57.1^{a}	15.7^{b}	14.4^{a}	239.0^{b}	8.6^{a}	8.0^{b}
	2.5	57.2^{a}	17.7^{a}	13.9^{a}	249.1^{ab}	7.4^{a}	9.5^{b}
	5.0	56.4^{a}	18.4^{a}	13.4^{a}	256.1^{a}	9.2^{a}	19.6^{a}
	7.5	57.0^{a}	18.1^{a}	13.4^{a}	252.2^{a}	10.1^{a}	18.4^{a}
	SED	0.85	0.61	0.39	4.85	1.09	2.91
	P	NS	0.002	NS	0.018	NS	0.01
F[2]	25	54.1^{b}	21.7^{b}	12.2^{b}	281.3^{b}	9.3^{a}	18.1^{a}
	10	59.5^{a}	13.2^{a}	15.3^{a}	216.9^{a}	8.4^{a}	9.6^{b}
	SED	0.60	0.43	0.28	3.43	0.77	2.05
	P	<0.05	<0.01	<0.01	<0.01	NS	0.01

[abcd]Mean values in the same column bearing different superscripts are significantly different (P<0.05). [1]I, % Inulin; [2]F, % Fat; [3]EV, energy value (Kcal/100g cooked sausage); [4]CL, % cook loss; [5]ES, emulsion stability.

The calorific value decreased from an average of 281.3 kcal/100g in the standard sausages to 216.9 kcal in the cooked reduced fat sausages and represents an average energy reduction of 23%. Fructan analysis showed that the prebiotic fibre remained stable following cooking (average 2.3%). Fat reduction and the addition of inulin at 5 and 7.5%, reduced (P<0.001) the emulsion stability of the sausages. The addition of inulin and the level of fat had no effect (P>0.05) on cooking losses. In cooked sausages the addition of inulin at 5 and 7% increased L* values. Fat reduction lowered (P<0.001) L* and increased (P<0.001) a* values (data not shown).

Reduced fat sausages containing 5% inulin had the highest (P<0.001) chewiness and gumminess (Table 3) while no effects (P>0.05) were recorded in hardness and springiness. No trends could be observed in chewiness, cohesion or gumminess parameters even though minor significant differences were found between some treatments.

Table 3 Texture Profile analysis of cooked sauages

Treatment Fat %	Inulin %	Hard[1] (N)	Chew[2] (N)	Co[3] (ratio)	Gum[4] (N)	Spr[5] (mm)
25	0	61.4^{a}	155.3^{b}	0.5^{e}	19.7^{cd}	7.9^{a}
	2.5	53.2^{a}	153.9^{b}	0.6^{e}	19.0^{cde}	8.2^{a}
	5.0	49.2^{a}	147.1^{cd}	0.6^{cd}	18.8^{de}	7.9^{a}
	7.5	47.3^{a}	139.1^{e}	0.7^{ab}	18.0^{e}	7.8^{a}
10	0	68.7^{a}	144.1^{de}	0.7^{a}	20.1^{c}	7.3^{a}
	2.5	58.1^{a}	156.9^{b}	0.7^{ab}	22.1^{b}	7.2^{a}
	5.0	58.1^{a}	165.6^{a}	0.7^{bc}	23.9^{a}	7.0^{a}
	7.5	58.6^{a}	151.7^{bc}	0.6^{d}	21.8^{b}	7.0^{a}
	SED	7.27	2.84	0.015	0.613	0.130
	P	NS	<0.001	<0.05	<0.001	NS

[abcd]Mean values in the same column bearing different superscripts are significantly different (P < 0.05). [1]Hardness, [2]Chewiness, [3]Cohesion force, [4]Gumminess, [5]Springiness.

These results indicate that fat reduction had a greater effect on sausage textural properties compared to the effect of inulin addition.

Table 4 Sensory properties of standard and reduced fat breakfast sausages with different concentrations of inulin.

Treatment Fat %	I %	OA[1]	OL[2]	Ten[3]	Flav[4]	Juic[5]	PI[6]
25	0	5.2^{a}	4.7^{bc}	5.1^{ab}	5.0^{ab}	4.7^{bc}	4.1^{ab}
	2.5	4.9^{a}	5.3^{a}	5.3^{a}	5.3^{a}	5.3^{a}	4.7^{a}
	5.0	5.4^{a}	5.1^{ab}	5.2^{a}	5.4^{a}	5.2^{ab}	4.5^{ab}
	7.5	5.1^{a}	4.9^{ab}	5.1^{ab}	5.0^{ab}	5.1^{ab}	4.3^{ab}
10	0	4.7^{a}	4.3^{cd}	4.3^{cd}	4.5^{bc}	4.0^{d}	3.3^{d}
	2.5	4.9^{a}	4.7^{c}	4.7^{bc}	4.8^{bc}	4.2^{cd}	4.0^{bc}
	5.0	5.0^{a}	4.1^{de}	4.3^{cd}	4.3^{cd}	4.0^{d}	3.4^{cd}
	7.5	4.3^{b}	3.8^{e}	4.2^{d}	4.0^{d}	3.5^{e}	3.0^{d}

[abcd]Mean values in the same column bearing different superscripts are significantly different (P < 0.05). [1]Overall appearance, [2]Overall liking, [3]Tenderness liking, [4]Flavour liking, [5]Juiciness liking, [6]Purchase intent.

Sensory analysis (Table 4) showed that inulin is well accepted from a sensorial view point in both standard and reduced fat breakfast sausages with the exception of 7.5% inulin in reduced fat sausages.

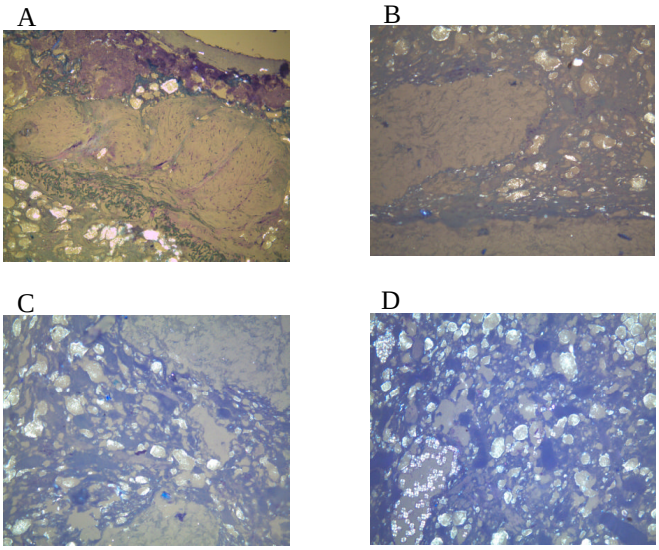

Fig 1. Light microscopy micrographs of standard and low fat pork breakfast sausages containing different inulin levels (magnification 10x): (A) control sausage (B) reduced fat control (C) reduced fat sausage containing 2.5% inulin (D) reduced fat sausage containing 7.5% inulin

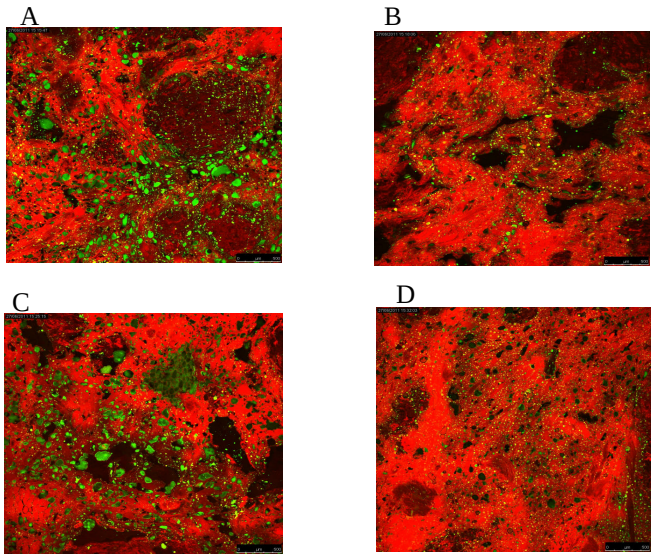

Fig 2. CSLM micrographs of standard and low fat pork breakfast sausages containing different inulin levels (low magnification): (A) Standard control sausage (B) reduced fat control (C) reduced fat sausage containing 2.5% inulin (D) reduced fat sausage containing 7.5% inulin

The images show the microstructure (fig. 1) of the standard control sausage (22% fat) and low fat pork breakfast sausages containing 0% (control), 2.5% and 7.5% inulin respectively at medium magnification. Fig 1 (D) shows clusters of inulin crystals at 7.5%. CLSM (Fig 2) gives a better idea of the fat distribution (green stain) in the sausage samples. The effect of inulin on the sausage texture is not detected using CLSM. When excited by the laser, viable cells (fat) fluoresce green whilst non-viable cells fluoresced red (protein).

IV. CONCLUSIONS

It is possible to manufacture a standard pork breakfast sausage consisting of up to 5% inulin in the final product without significant detrimental changes in the overall product. It is also feasible to produce an acceptable hypocalorific breakfast sausage with 23% less kcal/100g sausage enriched with 2.5% prebiotic fibre without sacrificing overall sensory and quality attributes.

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