The effects of cereal additives in low-fat sausages and meatballs. Part 2: Rye bran, oat bran and barley fibre

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ABSTRACT

Rye bran, oat bran and barley fibre have been compared as additives in low-fat sausages and meatballs. The water/protein ratio and starch content were constant to allow direct comparisons. Oat bran was the best alternative in low-fat sausages due to its gelling ability upon heating. These sausages exhibited low process (0.9%) and frying losses (10.5%), and high values of firmness (11.0 N) and sensory acceptance. The sausages containing barley fibre, with the highest amount of soluble β-glucan, had high losses (3.8% and 19.5%) and the lowest firmness (4.6 N). Rye bran was suitable in meatballs, probably due to its particulate nature, which is more acceptable in this type of meat product, where the gelling properties are not as important as in sausages. There was no significant difference between the firmness of meatballs containing rye bran (6.1 N) and the reference (7.5 N), after pan-frying. Meatballs with oat bran or barley fibre were less firm (3.6 N and 2.0 N).

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1. Introduction

An increase in dietary fibre (DF) intake is desirable as the recommended daily intake (25–35 g) for the maintenance of health and prevention of diseases rarely is achieved by the population in Western countries (Gray, 2006). Sausages and meatballs are frequently eaten products and their fat content is normally high. Decreasing the fat content of these products while simultaneously increasing the amount of DF would lead to healthier products. However, it is difficult to maintain high water-holding capacity, good texture and sensory attributes of low-fat meat products (Bengtsson, Montelius, & Tornberg, 2011; Claus, Hunt, & Kastner, 1990; Troy, Desmond, & Buckley, 1999).

Cereal DF may be a good option to be used as additive in low-fat meat products. The outer layer of the kernel of cereals, bran, is very rich in DF. Rye bran consists mainly of insoluble arabinoxylans (AX) and cellulose (Andersson, Eliasson, Selénare, Kamal-El-Din, & Åman, 2003), while oat bran contains a higher proportion of soluble DF, mainly β-glucans (Wood, 1994). β-Glucans are linear homopolysaccharides of β-D-glucopyranosyl residues linked via β-(1 → 3) and β-(1 → 4) linkages, mainly forming (1 → 3)-linked cellobiopyranosyl and (1 → 3)-linked cellotetraosyl units (Wood, Weisz, & Blackwell, 1994). Oat β-glucans have a higher molecular weight than barley β-glucans (Beer, Wood, & Weisz, 1997) and a lower ratio of tri- to tetramers; around 2, compared to 3 in barley (Cui, Wood, Blackwell, & Nilforuk, 2000).

Previous studies have been performed to evaluate the effects of adding DF-rich cereal materials to meat products with a reduced fat content, some examples being rye bran, oat fibre, barley β-glucan, and wheat fibre (Cofrades, Hughes, & Troy, 2000; Mansour & Khalil, 1999; Morin, Temelli, & McMullen, 2002; Petersson, Godard, Eliasson, & Tornberg, 2014). However, different cereal materials are rarely compared in the same study, and different types of low-fat meat products are not often evaluated together. Therefore, the cause of the changes in important properties, such as texture, when adding DF to low-fat meat products is not yet well understood. A comparison of two meat products, sausages and meatballs, is interesting since the structure of these differs and that an addition of DF may not necessarily have the same effect on the products. Sausages consist of a strong meat protein network while meatballs have a more particulate structure.

This study was carried out to investigate whether fibre-rich cereal materials could be successfully incorporated into low-fat sausages and meatballs, in an effort to improve our understanding of how texture and other properties are affected by the addition of cereal DF. Effects on water-holding capacity, texture and sensory properties were studied. Finally, effects of the three cereal materials were compared in sausages and meatballs.

2. Materials and methods

2.1. Cereal material

Rye bran and oat bran (Lantmännens, Sweden) and barley fibre (Lyckeby Stärke, Sweden) were used as fibre-rich additives. Each was ground in a mill (Retch ZM1, Germany) and passed through a 0.5 mm screen. The DF contents of these materials have been analysed previously (Petersson, Bengtsson, Nyman, Eliasson, & Tornberg, 2012).
The rye bran consisted of 25.6% AX, 4.2% β-glucans and a total DF content of 36%. The oat bran consisted of 5.2% AX, 10.2% β-glucans (3.3% soluble β-glucans) and a total DF content of 18.4%. The barley fibre used in this study had an AX content of 20.8% and a total DF content of 63.2%. It had a total β-glucan content of 32%, including a very high proportion of soluble β-glucans, 22.3%. Most of the AX were insoluble: 91% of the rye bran AX, 98% of the oat bran AX and 88% of the barley fibre AX.

2.2. Sausage and meatball preparation

Three different recipes were prepared for both the meatballs and the sausages, in order to be able to study the effects adding fibres and to be able to compare if adding fibres could result in similar products as the ones with higher fat and starch content. The first contained the normal amounts of fat and starch in these products, and is described as high-fat, high-starch products (denoted HPHS). The second had a low fat content and a high starch content (denoted LPHS), while the third had low levels of both fat and starch (LFLS). The various kinds of cereal fibre were added to the LFLS samples.

The sausages were prepared according to the recipes given in Table 1. Low-fat pork (43.3% fat) and low- and high-fat beef (3.4% and 17.7% fat) provided by Ugglarps AB, Sweden, were used. Potato flour (containing 80.6% starch, 16% water) was obtained from Lyckeby Stärkelsen (Sweden). The water/protein ratio of 7.9 was kept constant for all recipes and the salt content was 2%. The total DF content in the sausages with added rye bran was 1%. The total amount of starch added was 4% (low) or 8% (high).

The ingredients were mixed together and meatballs of 15 g were rolled and pan-fried or deep-fat-fried as described previously (Pettersson et al., 2014).

2.3. Sausage and meatball analysis

2.3.1. Water, fat and total frying loss of meatballs and process and frying loss of sausages

Process loss (L) was calculated by measuring the difference in weight before and after boiling the sausages or frying the meatballs, and expressed as a percentage of the initial weight. The water content of meat batters (n = 3), cooked sausages (n = 4), and fried meatballs (n = 4) were measured on 5 g samples, dried overnight at 102 °C.

Water and fat loss were calculated according to following equations:

\[ a = \frac{W_l - (W_f \times (100 - L))/100[\%]}{1} \]

\[ b = \frac{L-a[\%]}{2} \]

where a is the water loss, W_l is the water content of the batter, and W_f is the water content of the cooked sausage or fried meatball. L denotes the process loss for the sausages or the frying loss for the meatballs and b is the fat loss.

Slices of sausage, 1 cm thick, were fried for 2 min on each side in a pan preheated to 174 °C, to a centre temperature of about 72 °C, and then left to cool at room temperature. The frying loss was obtained by weighing the slices of sausage before and after frying, and is expressed as a percentage of the initial weight. Measurements were made on 16 slices of each kind of sausage.

2.3.2. Texture analysis

Texture measurements were performed on cooked sausages and fried meatballs using a Texture Analyser (TA-XT2i, Stable Micro Systems, Gorthing, England) equipped with a 5 kg load cell and a cylindrical probe with a diameter of 36 mm. The firmness was measured as the maximum force (N) required to compress a 10 mm² sample cube by 50% at a speed of 1 mm/s. Three replicate samples were tested from each recipe (duplicate batches).

2.3.3. Sensory evaluation

A hedonic sensory test was performed on the fried sausages and pan-fried meatballs by an untrained panel of 16 participants. Six attributes of the sausages and meatballs were evaluated on a scale from 1 to 9: colour (very light — very dark), crumbliness (smooth — grainy), compactness (not compact — very compact), meat taste intensity (none — very high), off-flavour (none — very high), and total impression (very poor—very good). Juiciness (dry—very juicy) was also evaluated for the meatballs. A more detailed description has been given previously by Pettersson et al. (2014).

2.4. Rheology of cereal additives

To be able to compare the contribution of added cereal materials to the texture of the sausages, they were mixed together with potato starch and water in the same proportions as in the sausage recipes, but without meat. Mixtures with only cereals and water and no potato starch were also prepared. The mixtures were heated in the same manner as when cooking the sausages. The heated fibre and starch samples were stored in a refrigerator (7 °C) overnight and then analysed at room temperature (20 °C) using a rheometer with an oscillatory stress sweep between 0.1 and 100 Pa at 1 Hz (StressTech, Reologica AB, Sweden), in a bob and cup geometry.

Table 1

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>HPHS%</th>
<th>LHS%</th>
<th>LFLS%</th>
<th>Rye bran</th>
<th>Oat bran</th>
<th>Barley fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sausages</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water/ice</td>
<td>41.1</td>
<td>43.9</td>
<td>48.2</td>
<td>45.2</td>
<td>44.7</td>
<td>45.5</td>
</tr>
<tr>
<td>Meat*</td>
<td>48.4</td>
<td>45.6</td>
<td>47.3</td>
<td>46.4</td>
<td>45.8</td>
<td>46.7</td>
</tr>
<tr>
<td>Spices and additives²</td>
<td>2.57</td>
<td>2.57</td>
<td>2.57</td>
<td>2.57</td>
<td>2.57</td>
<td>2.57</td>
</tr>
<tr>
<td>Potato flour</td>
<td>8.0</td>
<td>8.0</td>
<td>4.0</td>
<td>2.9</td>
<td>1.0</td>
<td>3.6</td>
</tr>
<tr>
<td>Cereal additive</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2.5</td>
<td>0.0</td>
<td>1.7</td>
</tr>
<tr>
<td>Soluble DI³</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.08</td>
<td>0.31</td>
<td>0.39</td>
</tr>
<tr>
<td>Soluble β-glucan</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.03</td>
<td>0.18</td>
<td>0.33</td>
</tr>
<tr>
<td>Total β-glucan</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.11</td>
<td>0.55</td>
<td>0.48</td>
</tr>
<tr>
<td>Total AX</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.68</td>
<td>0.28</td>
<td>0.31</td>
</tr>
</tbody>
</table>

| Meatballs  |       |      |       |          |          |              |
| Water      | 17.9  | 24.7 | 27.6  | 29.8     | 26.5     | 27.1         |
| Meat*      | 51.3  | 44.5 | 46.7  | 46.0     | 45.3     | 46.3         |
| Onion      | 11.6  | 11.6 | 11.6  | 11.6     | 11.6     | 11.6         |
| Potato flour | 8.7   | 8.7  | 3.6   | 2.8      | 1.5      | 3.4          |
| Salt       | 1.3   | 1.3  | 1.3   | 1.3      | 1.3      | 1.3          |
| White pepper | 0.1   | 0.1  | 0.1   | 0.1      | 0.1      | 0.1          |
| Cereal additive | –     | –    | –     | 2.1      | 4.3      | 1.3          |
| Soluble DI³ | –     | –    | –     | 0.06    | 0.22     | 0.31         |
| Soluble β-glucan | –     | –    | –     | 0.02    | 0.13     | 0.27         |
| Total β-glucan | –     | –    | –     | 0.08    | 0.40     | 0.38         |
| Total AX   | –     | –    | –     | 0.49    | 0.20     | 0.25         |

¹ 60% pork and 40% low- or high-fat beef.
² Black pepper (0.1 g), nitrite salt (0.72 g), vacuum salt (1.28 g), ascorbic acid (0.02 g), polysorbate (0.15 g) and liquid smoke (0.3 g).
³ Amount of soluble DI added by the cereal additive.
⁴ Low- or high-fat beef.
⁵ HPHS — High Fat, High Starch, LHS — Low Fat, High Starch, and LFLS — Low Fat, Low Starch.
Table 2
Process loss, frying loss and firmness of sausages (mean and standard deviation).

<table>
<thead>
<tr>
<th>Type of sausage</th>
<th>Process loss (%)</th>
<th>Frying loss (%)</th>
<th>Firmness (N)</th>
</tr>
</thead>
<tbody>
<tr>
<td>n = 24</td>
<td>n = 32</td>
<td>n = 6</td>
<td></td>
</tr>
<tr>
<td>HHFS</td>
<td>1.2 ± 0.1*</td>
<td>8.2 ± 0.3*</td>
<td>12.2 ± 0.8*</td>
</tr>
<tr>
<td>LHFS</td>
<td>0.7 ± 0.1*</td>
<td>10.5 ± 0.5*</td>
<td>11.8 ± 0.8*</td>
</tr>
<tr>
<td>LFLS</td>
<td>1.1 ± 0.1*</td>
<td>13.2 ± 0.4*</td>
<td>12.6 ± 0.7*</td>
</tr>
<tr>
<td>Rye bran</td>
<td>2.8 ± 0.3*</td>
<td>22.8 ± 0.7*</td>
<td>7.4 ± 0.9*</td>
</tr>
<tr>
<td>Oat bran</td>
<td>0.9 ± 0.0*</td>
<td>10.9 ± 0.5*</td>
<td>11.0 ± 0.4*</td>
</tr>
<tr>
<td>Barley fibre</td>
<td>3.8 ± 0.4*</td>
<td>19.6 ± 1.1*</td>
<td>4.5 ± 0.9*</td>
</tr>
</tbody>
</table>

Different letters in the same column indicate significant differences (p < 0.05).

1. HHFS — High Fat, High Starch, LHFS — Low Fat, High Starch, and LFLS — Low Fat, Low Starch.

2.5. Microscopy

The same mixtures of cereal material, potato starch and water (described in 2.4) were studied before and after heating to 75°C, with a light microscope (Nikon Optiphot, Nikon, Tokoyo, Japan) with 50 times magnification. A minimum of five photos per duplicate were taken.

2.6. Statistical analysis

The results were analysed statistically using one-way analysis of variance (ANOVA) and the Pearson correlations (r) of the variables were analysed with Minitab (version 14, Minitab Inc. USA). Statistically significant differences between samples were defined as p < 0.05.

3. Results and discussion

3.1. Water, fat and total process loss

The results regarding the process and frying losses, and firmness of the sausages and meatballs are given in Tables 2 and 3, respectively. The results for the three reference samples have been presented previously by Peterson et al. (2014) and are given here to enable comparisons with all recipes and not only the LFLS recipe.

The process losses of the sausages without fibre and those containing oat bran were rather low, around 1%, but the losses from sausages containing rye bran and barley fibre were significantly higher: 2.8 and 3.8%, respectively. The process loss of the sample containing oat bran did not differ from the references (0.9%). All the sausages showed very low fat losses during processing (0.4%) and are therefore not presented in Table 2. This is in agreement with previous findings (Andersson, Andersson, & Tornberg, 2000). Significant differences were found in the frying losses of the various kinds of sausage, which are given in Table 2. Once again, sausages containing oat bran showed the lowest loss of the three fibre-containing sausages (10.9%), which was not significantly higher than the losses of the LHFS or the LFLS sausages. It has previously been shown that adding oat fibre to low-fat sausages can improve the cooking yield (Aleson-Carbonell, Fernandez-Lopez, Perez-Alvarez, & Kuri, 2005; Hughes, Cofrades, & Troy, 1997).

The addition of barley fibre resulted in a higher frying loss of 19.6%, which is contradictory to the study by Morin, Temelli, and McMullen (2004). When rye bran was added to the sausage batter the frying loss increased to 22.8%, which was significantly higher than the losses of all other sausages. The lowest frying loss was observed in the HHFS sausage, demonstrating the importance of fat and starch for the water-holding capacity of sausages.

The total frying loss of the pan-fried meatballs was reduced by the addition of oat bran and barley fibre (21.5% and 25.0%) compared with the LFLS meatballs (32.7%), and was similar to the total frying losses of the HHFS and the LHFS meatballs (Table 3). Decrease of the frying loss as the result of adding oat or barley fibre to low-fat meat patties has also previously been shown (Kumar & Sharma, 2004; Pinero et al., 2008).

Rye bran had a higher frying loss (30.2%) than oat bran and barley fibre but was not significantly different from LHFS or LFLS. In deep-fried meatballs the addition of barley fibre reduced the frying loss compared to the LFLS meatballs, while the improvement when adding oat bran was similar but not significantly lower than LFLS. However, neither oat bran nor barley fibre had any significantly effect on frying losses compared to the references with high starch contents. Rye bran had the highest frying loss during deep-frying (27.6%), similar to the LFLS. The fat uptake (negative fat loss) during deep-frying was also higher in the meatballs containing oat bran and barley fibre than in the LFLS meatballs and the meatballs with added rye bran.

None of the sausages containing cereals had as low frying loss as the HHFS sausages. However, the addition of oat bran or barley fibre to the LFLS meatballs reduced the frying loss, and these values were comparable with those of the HHFS meatballs.

3.2. Texture analysis

All three sausage recipes with no added fibre exhibited similar values of firmness, but considerable variations were observed when the different cereals fibres were added (Table 2). When adding oat bran, the firmness of the sausages was as high as for the reference sausages (11.0 N). The addition of rye bran and barley fibre significantly decreased the firmness, showing values of 7.4 and 4.6 N, respectively. Morin et al. (2002) added soluble barley β-glucans to low-fat (12%) sausages at concentrations of 0.3 and 0.8%, and found that 0.3% β-glucan was better, since 0.8% β-glucan resulted in a soft sausage with a low firmness. In the present study, addition of barley fibre containing 0.33% soluble β-glucan (Table 1) was more detrimental to the firmness of the sausages than the addition of oat bran containing 0.18% soluble β-glucan. It is commonly believed that adding higher amounts of soluble β-glucan improves the firmness of a meat product (Lazaridou & Biladeris, 2007), which is contrary to these experimental observations. The reason for this behaviour will be discussed below.

The potato starch content governs the texture of the pan-fried and deep-fried meatballs, and all low-starch recipes, with and without cereal fibre, exhibited lower firmness than the HHFS and LHFS meatballs (Table 3). No significant differences in firmness were found between the

Table 3
Water, fat and frying loss and firmness of meatballs using two kinds of frying (mean and standard deviation).

<table>
<thead>
<tr>
<th>Type of meatball</th>
<th>Pan frying</th>
<th>Deep fat frying</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water loss (%)</td>
<td>n = 2</td>
<td>n = 6</td>
</tr>
<tr>
<td>Fat loss (%)</td>
<td>n = 2</td>
<td>n = 6</td>
</tr>
<tr>
<td>Total frying loss (%)</td>
<td>n = 2</td>
<td>n = 6</td>
</tr>
<tr>
<td>Firmness (N)</td>
<td>n = 6</td>
<td>n = 6</td>
</tr>
<tr>
<td>HHFS</td>
<td>20.8 ± 0.1*</td>
<td>0.3 ± 0.1*</td>
</tr>
<tr>
<td>LHFS</td>
<td>26.0 ± 0.6*</td>
<td>0.4 ± 0.4*</td>
</tr>
<tr>
<td>LFLS</td>
<td>31.7 ± 0.4*</td>
<td>1.0 ± 0.4*</td>
</tr>
<tr>
<td>Rye bran</td>
<td>29.3 ± 1.9*</td>
<td>0.0 ± 0.2*</td>
</tr>
<tr>
<td>Oat bran</td>
<td>21.6 ± 0.1*</td>
<td>0.0 ± 0.1*</td>
</tr>
<tr>
<td>Barley fibre</td>
<td>25.0 ± 0.9*</td>
<td>0.0 ± 0.2*</td>
</tr>
</tbody>
</table>

Different letters in the same column indicate significant differences (p < 0.05).

1. HHFS — High Fat, High Starch, LHFS — Low Fat, High Starch, and LFLS — Low Fat, Low Starch.
meatballs with low starch content, with or without fibre addition, when they were deep-fried. When pan-frying, however, meatballs containing rye bran exhibited a higher firmness than those containing barley fibre. Meatballs containing rye bran were the only fibre-containing meatballs with a firmness comparable to that of the LFS meatballs without fibre. This could be due to the higher frying loss of the rye bran meatballs than the oat bran and barley fibre meatballs, giving rise to a more compact meatball after frying. In the case of deep-fried meatballs, the difference in frying loss of the rye bran meatballs was the same as those from oat bran and barley fibre meatballs. The fat uptake of the oat bran and barley fibre meatballs during deep-frying was higher than in the rye bran meatballs, which could have contributed to the increase in firmness of the oat bran and barley fibre meatballs. A more probable reason for the increased firmness of meatballs containing rye bran is the more particulate nature of rye bran than the other cereal fibres studied, which is clearly demonstrated in the rheological results presented below. It has been shown by Andersson, Andersson, and Tomberg (1997) that the microstructure of meatballs is particulate, in contrast to the gel meat network seen in sausages and, therefore, the addition of solid particles like rye bran could contribute to the firmness of meatballs but not of sausages.

3.3. Rheology and micrographs of cereal additives

The results of some of the rheological measurements on the combinations of the different cereal additives with water and with or without potato starch are shown in Fig. 1. The mixtures containing rye bran did not create a gel, with or without the addition of potato starch (results not shown). In both cases the rye bran particles sedimented rapidly. Barley fibre in water did not form a gel either, and very low values of the elastic modulus (G') and the viscous modulus (G'') were recorded (results not shown). When a mixture of oat bran, water and potato starch was heated, a strong gel was created, with a high value of G', as can be seen in Fig. 1. The value of G' was much higher than G" in the linear viscoelastic region, where G' is independent of shear stress.

A mixture of oat bran and water also created a gel, with a value of G' almost as high as that of the barley fibre together with water and potato starch. The ability of fibre to form a gel is evidently important in maintaining the properties of the sausages with fibre addition. The water-holding capacity of the sausages during frying (Table 2) followed the same order as the ability of the cereal additives to form a gel when heated together with potato starch in water (Fig. 1).

The total amount of starch (cereal and potato) was kept constant. The ratios of potato starch to cereal starch will however differ, since different amounts of cereal material were added in order to obtain a DF concentration of 1% in the meat products. There is also a considerable difference between cereal starch and potato starch regarding size and their ability to swell. Potato starch gelatinizes between 55 and 75 °C and swells much more than other starches. Potato starch is often used in sausage recipes because of its high water-holding capacity. The high water-holding capacity of sausages is due to the simultaneous gelling of the meat protein, which starts at 53 °C, and the swelling of the starch granules (Tornberg, Andersson, & Asplund, 1998). According to the same study, barley starch starts to swell at 61 °C, and is not effective in taking up the water expelled from the protein network of the meat. The swelling factor at 80 °C for oat starch has been reported to be 8.6–100.0 (Tester & Karkalas, 1996) that for barley starch, 10.2–13.7 (Tester & Morrison, 1992) and for rye starches in the range of 7.8–13.7 (Buksa et al., 2010). Potato starch, on the other hand, has the ability to swell over 100 times at 80 °C (Elissaw, 1986). Although the amount of potato starch is much lower in the oat bran sausages, the ability to form a gel and lower the frying losses is higher, which implies that the amount of potato starch is not the dominating reason for the change of the properties of the sausages in this investigation. Barley β-glucans have been shown to be able to form gels at concentrations above 4%, when allowed to set for 24 h at room temperature (Burkus & Temelli, 1999). The concentrations used in this study were lower: 0.55 and 0.48% in the sausages containing oat bran and barley fibre, respectively. Oat β-glucans usually have a higher molecular weight than barley β-glucans (Beer et al., 1997), and a lower tri- to tetramer ratio (Cui et al., 2000), which might explain the better ability of oat bran to create a gel making it more suitable for incorporation in sausages.

Micrographs of the three cereal materials mixed with water and potato starch in the same proportions as the recipes without the meats can be seen in Fig. 2. The left-hand column shows the micrographs for the oat bran mixture before (Fig. 2A) and after (Fig. 2D) heating. Upon heating, the oat bran material itself seems to create a gel network when mixed in water, as indicated by the rheological measurements on the oat bran in water without any potato starch. The swollen potato starch granules lie within this network, thereby improving the strength of the gel even further. In the case of barley fibre, the continuous phase seen in the micrograph after heating (Fig. 2E) consists of the swollen potato starch. The barley fibre is in between the starch granules and cellulose filaments.
the gel created is not as strong as in the case of oat bran together with potato starch. The rye bran did not have the ability to create a gel upon heating, as can be seen in Fig. 2F, where the large rye bran particles together with the potato starch do not fill the entire space. A considerable difference was seen upon inspecting the mixtures visually, in that the rye bran particles sedimented quickly.

3.4. Sensory evaluation

Among the sausages containing cereal fibre, the sensory panel preferred those with oat bran (Table 4). The total impression of these sausages was as good as any of the references. Although the total impressions of the rye bran and barley fibre sausages were significantly lower than that of the oat bran sausages, they were not significantly lower than that of the HFHS sausages.

The crumbliness of the sausages containing oat bran was lower than that of the other two sausages containing cereal fibre, while the firmness was higher. Low crumbliness is usually correlated to good gel-forming properties, which is consistent with the finding that the oat bran formed the best gel of the additives studied (Fig. 1) and there is a correlation between the G' and crumbliness of the sausages ($p < 0.001$, $r = -0.34$). The sensory panel judged the barley fibre sausages to have the lowest compactness (3.5), although this was not significantly different from that of the LFLS sausages, which corresponds to the lowest firmness observed in the texture measurements. The compactness of the sausages evaluated by the sensory panel was correlated to the firmness measured by the texture analyser ($p < 0.001$, $r = 0.26$). No difference was found in the compactness of the sausages containing oat bran or rye bran (4.9 and 5.0), although their firmness differed significantly (11.0 and 7.4 N). The total impression of the sausages was correlated to the meat taste intensity and the off-flavour ($p < 0.001$, $r = 0.46$ and $r = -0.36$), which is in agreement with previous studies of low-fat sausages (Bengtsson et al., 2011; Petersson et al., 2014).

There were no significant differences between the total impressions of the meatballs (Table 5). However, significant differences were noted in the perceived juiciness, crumbliness, compactness and colour of the meatballs. The barley fibre meatballs were perceived as being juicier than those containing oat bran and were comparable to the LFLS meatballs. The oat bran meatballs were given a very low value of crumbliness, which may have been perceived as negative, since the value of the total impression was lowest for the oat bran meatballs, although it was not significantly different from the others. The compactness of the two kinds of meatballs with high starch contents was significantly higher than for the rest of the meatball samples, which is consistent with the substantially higher firmness of these two types of meatballs compared to the others. The firmness measured by the texture analyser corresponds to the compactness ($p < 0.001$, $r = 0.79$), and also to crumbliness and juiciness ($p < 0.001$, $r = 0.29$ and $r = -0.48$). It was also noted by the panel that the colour of the LFLS meatballs and those with oat bran was significantly lighter than that of the other meatballs. As for the sausages, there was a correlation between the total impression of the meatballs and the meat taste intensity and the off-flavour ($p < 0.001$, $r = 0.52$ and $r = -0.34$).

4. Conclusions

Due to its gelling ability upon heating, oat bran was found to be the most suitable for addition to low-fat sausages, and these exhibited low process andrying losses, together with high values of both firmness
and sensory acceptance. When adding oat bran to the meatballs, the result was a smoother texture, i.e., lower crumbliness, than for the other meatballs; however, this did not appear to be a preferable attribute for meatballs.

Rye bran is suitable for addition to meatballs, probably due to its particulate nature, which is more acceptable in this type of meat product, where the gelling properties are not as important as in sausages. The firmness of meatballs containing rye bran was as high as the reference with same amount of starch when pan-fried, which was not the case for the two other cereal additives studied. This difference was also reflected in the sensory evaluation of the crumbiness of the meatballs with the different cereal additives.

The addition of barley fibre, which has the highest content of soluble β-glucan (22.3%), led to the same high process and frying losses as the addition of rye bran, and the lowest firmness in sausages. Evidently, barley fibre is not a good additive in sausages despite its high content of β-glucan and a large soluble fraction. This was also confirmed in the rheological measurements, where it was found that the heated mixture of barley fibre with water and potato starch had a poor gel-forming ability. However, the addition of barley fibre may be suitable in meatballs, as the frying loss is reduced compared to the low-fat, low-starch reference.

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References


