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INSIGHT INTO THE CHEMICAL COMPOSITION OF WHEAT USED IN EUROPEAN BROILER DIETS

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Highlights for the paper entitled "Wheat used in European broiler diets varies widely in non-starch polysaccharide composition".

- Wheat from 15 European countries and collected over 5 years of harvest was studied.
- The observed variability was the largest for the WE-fraction of the NSP.
- WE-NSP concentration was positively correlated with extract viscosity.
- The results confirm the variable composition of European wheat batches.

ABSTRACT

In Europe, wheat is commonly used in broiler diets. The chemical composition and energy value of wheat can vary considerably between different wheat cultivars or due to different growing and post-harvest storage conditions. The current study assessed the chemical composition in 153 batches of wheat used for poultry feeds from 15 European countries over 5 years of harvest. The non-starch polysaccharide (NSP) -composition, the concentration of starch and protein and the extract viscosity were analysed. The concentration of starch and protein ranged between 558 and 680 g/kg dry matter (DM) and 92 and 173 g/kg DM respectively. The concentration of water-extractable (WE) and water-unextractable (WU) NSP ranged between 8.7 and 18.3 and 58.1 and 99.6 g/kg DM respectively. The variation was the largest in the WE fraction of the NSP (CV 14.3%). The concentration of WE-NSP was positively correlated with extract viscosity (r = 0.46; $P < 0.001$) and this was caused by the WE-arabinoxylan fraction (r = 0.59; $P < 0.001$) in particular. In conclusion, the present results confirm the variable composition of European wheat batches, especially for the WE-fraction of the NSP and highlight the need for considering the concentration of NSP in the practice of feed formulation.

Keywords: wheat; non-starch polysaccharides; variability; chemical composition; correlation analysis

INTRODUCTION

Wheat is the most important cereal in Europe. In 2011, the harvest of cereals in the European Union was around 289 million tonnes, with wheat accounting for 132 million tonnes or almost half of the European cereal production (Eurostat, 2012). Around 40% of wheat production is used for animal feed (Global Agricultural Information Network, 2013). In Europe, wheat is commonly included in poultry diets as an energy source in high percentages of up to 600 g/kg or more. In Denmark, for example, wheat can comprise 70 to 80% of the broiler finisher diet (Steenfeldt et al., 1998a). To calculate the metabolizable energy (ME) of feed, tabular values for most feed ingredients are applied, such as the ones provided by the National Research Council (NRC, 1994). It is well known, however, that the nutritional value of wheat can vary considerably, especially for broiler chickens. Ranges between 8.4 and 15.9 MJ/ kg dry matter (DM) for the apparent metabolizable energy (AME) of wheat have been reported (Annison, 1991; Austin et al., 1999; Choct et al., 1999; Mollah et al., 1983). This results in a variable production efficiency (Barteczko et al., 2009; Gutierrez del Alamo et al., 2008; Steenfeldt, 2001). The variation in nutritional value and broiler performance has been related to several chemical compounds and physical properties of wheat (Carré et al., 2002; Hetland et al., 2007; Rose et al., 2001; Wiseman, 2000). In particular, the non-starch polysaccharides (NSP) from wheat are considered as an important predictor for wheat AME (Annison, 1991; Austin et al., 1999; Choct et al., 1999; Dusel et al., 1997; Smeets et al., 2015). The predominant NSP in wheat are arabinoxylan (AX), mixed-linked (1→3), (1→4)-β-D-glucans (referred to here as β-glucans) and cellulose. The NSP can be divided into a water-extractable (WE) and a water-unextractable (WU) fraction. Several factors influence the chemical composition and therefore the energy

content of wheat, such as cultivar, growing conditions and post-harvest storage conditions (Bedford et al., 1998; Choct et al., 1999; Dornez et al., 2008; Kim et al., 2003; Scott et al., 1998). Studies to examine the variability in chemical composition and functional properties of wheat have been done for Australian wheat (Annison, 1991; Choct et al., 1999; Coles et al., 1997; Kim et al., 2003; Pritchard et al., 2011), Canadian wheat (Bedford et al., 1998; Jha et al., 2011; Scott et al., 1998; Sibbald et al., 1976; Zijlstra et al., 1999) and also for individual European countries, as shown in Table 1. The latter table provides an overview of studies which examined the chemical composition of wheat within a European country and a selection of the results obtained. Making comparisons between different studies, however, is not easy because of the wide diversity of analytical methods used. The methods for the measurement of protein and starch content are quite straightforward, whereas the determination of the NSP concentration is more difficult. In the practice of animal feed formulation, enzymatic-gravimetric methods such as the dietary fibre method described by Prosky et al. (1992) or the detergent fibre system (Van Soest et al., 1991) are commonly used. In scientific research, enzymatic-chemical methods are more common. The latter provide a more detailed analysis of the NSP fractions. Most researchers use procedures based on the method described by Englyst et al. (1994) or based on the Uppsala method (Theander et al., 1995). In these methods, the constituent sugars of the NSP are measured using gas-liquid chromatography (GLC) and the WE-NSP fraction is calculated from the difference between the total NSP and the WU-NSP fraction. On the other hand, some researchers determine the WE-NSP fraction separately by using various extraction procedures (Annison, 1991; Carré et al., 2002; Dornez et al., 2008; Saulnier et al., 1995).

The objective of the present study was to examine the chemical composition of wheat, with an emphasis on its NSP composition, not for a single country, but including different European

countries (15) over several years (five years of harvest), using one single method of analysis. In this way, the actual variation in the chemical composition of European wheat could be determined. The study was not designed to make correlations between the chemical composition of wheat and growing region or environmental conditions. Correlations between different wheat characteristics were studied.

MATERIAL AND METHODS

Wheat samples

In total 153 wheat batches were obtained from commercial feed mills over the European continent: Belgium (35), Germany (21), Russia (18), Norway (14), UK (13), France (10), Italy (9), Poland (8), Czech Republic (8), Ireland (5), Portugal (4), Sweden (3), Austria (2), Hungary (2) and Denmark (1). The samples were collected over five years of harvest: 2009 (9), 2010 (52), 2011 (70), 2012 (16), 2013 (6). Wheat samples were received from the feed mills throughout the year and were analysed within one month following receipt. Extra information regarding wheat cultivar, growing conditions or storage conditions at the feed mills was not available.

Chemical analyses

The NSP content was measured for all 153 samples, whereas the starch and protein content were determined for a subset of 122 samples (13 countries, first three years of harvest). As a functional characteristic, the extract viscosity was assessed on a subset of 69 samples (12 countries, first two years of harvest). All analyses were carried out at least in duplicate. Moisture contents were evaluated according to the AACC method 44-15A. The WE- and WU-NSP were measured separately using an enzymatic-chemical method, as described further. The dietary fibre

method was applied to separate the WE- and WU- fraction of the NSP (AACC 32-07). Instead of quantifying the NSP gravimetrically after the filtration step (AACC 32-07), the polysaccharides in the residues were further treated according to the procedure described by Englyst et al. (1994). In short, the polysaccharides in the residues were hydrolysed to monosaccharides by the addition of sulphuric acid and then quantified as alditol acetates by GLC. The constituent monosaccharide values were converted to the equivalent polysaccharide values using the conversion factor of 0.88 for pentoses (arabinose and xylose) and 0.90 for hexoses (mannose, galactose and glucose) (Bach Knudsen, 1997).WE- and WU-NSP were calculated as the sum of the constituent monosaccharides in the respective fractions (arabinose, xylose, mannose, galactose and glucose). The sum of arabinose and xylose was defined as AX. No correction was made for the presence of an arabinogalactan-peptide in the endosperm (Loosveld et al., 1997). Protein content was analysed using the Kjeldahl method (AACC 46-10) with a conversion factor for protein of 5.7. Starch content was assessed with an enzymatic kit supplied by Megazyme (Total Starch Assay, K-TSTA 04/2009, Megazyme International Ireland, Bray Co. Wicklow, Ireland), according to the instructions of the supplier. Extract viscosity was evaluated by incubating 10 g of ground wheat (through a 1 mm screen) in 30 mL deionized water for 30 minutes at 37°C under continuous stirring. This mixture was centrifuged for 2 minutes at 10,000 g (Dusel et al., 1997) and viscosity was determined at 37°C with a Brookfield cone and plate viscometer LV DV-II+ (Brookfield Viscometers Ltd., Essex, United Kingdom).

Statistical analyses

Pearson's correlation analyses between the various chemical constituents were conducted using Statgraphics Centurion XVI software (Statpoint Technologies, Inc., Warrenton, VA, USA).

RESULTS

Variability in wheat characteristics

The results of the analyses are shown in Table 2. Total NSP ranged between 68.4 and 112.2 g/kg DM. The coefficient of variation (CV) for total NSP was 8.8%. Total AX contributed for more than half of total NSP (64% on average) and its concentration varied between 43.4 and 73.6 g/kg DM. Small concentrations of mannose and galactose were also present. Another large fraction of NSP was provided by cellulose and β-glucan, which are both polysaccharides of glucose. These polysaccharides are represented by the value for glucose (GLU) in Table 2, whose concentration was between 19.3 and 35.0 g/kg DM.

Approximately 14.1% of total NSP was extracted with the current method and are to be considered as WE-NSP. WE-NSP ranged between 8.7 and 18.3 g/kg DM. Most of the WE-NSP is AX, ranging between 5.1 and 13.1 g kg^{-1}. In the current study, the average A/X ratio was higher for the WE-AX fraction (0.66) than for the WU-fraction (0.58). The CV% was 8.5 and 6.5 for the A/X ratio of WE-AX and WU-AX respectively.

The range in protein concentration was between 92 and 173 g/kg DM (CV 11.3%). In contrast to the variation observed for protein concentration (CV% 11.3), the variation of starch was lower (CV% 3.8). The concentration of starch in wheat was between 558 and 680 g/kg DM.

As a functional characteristic of wheat, the extract viscosity was assessed and it varied between 1.26 and 3.22 mPa.s (CV% 21.0). Table 3 shows the results for each country of origin or for each year of harvest separately. The highest concentration of WE-NSP was found in the wheat batches from Portugal (16.1 g/kg DM), followed by the UK (15.4 g/kg DM). The WU-

NSP concentration was the highest in the wheat batches from Austria (89.3 g/kg DM) and Ireland (86.9 g/kg DM).

Correlation analysis between different wheat characteristics

The results of the Pearson's correlation analysis between the different parameters for all wheat samples are shown in Table 4. Highly significant ($P < 0.001$) positive correlations ($r > 0.80$) were obtained between for example WU-AX and WU-NSP because the former constitutes a large part of the latter. Lower, but also highly significant ($P < 0.001$) positive correlations were obtained between for example WE-GLU and WE-NSP ($r = 0.37$). Because WE-GLU (presumably β-glucan) is part of the WE-NSP, these kinds of correlations were also evident.

Relatively high positive correlations ($r > 0.5$) were found between different fractions of the NSP, i.e. between WU-AX and WU-GLU ($r = 0.69$; $P < 0.001$) or between the total amount (TOT) of AX and TOT-GLU ($r = 0.57$; $P < 0.001$). For the WE fraction of the NSP, no significant correlation ($P > 0.05$) was detected between WE-AX and WE-GLU.

A relatively high negative correlation was obtained between the starch and protein content ($r = -0.63$; $P < 0.001$). In addition, a relatively high positive relation was found between the extract viscosity and WE-AX ($r = 0.59$; $P < 0.001$), while lower correlations were noted between extract viscosity and WE-NSP ($r = 0.46$; $P < 0.001$), TOT-AX ($r = 0.40$, $P < 0.01$) and TOT-NSP ($r = 0.33$; $P < 0.01$).

Low ($r > -0.5$), but highly significant negative correlations were found between starch and TOT-NSP ($r = -0.36$; $P < 0.001$) and between starch and the individual WU- and TOT-NSP fractions.

DISCUSSION