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Chemical and physicochemical characterisation of various horse feed ingredients

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ABSTRACT

There is an increasing need for identifying energy dense fibre rich feed ingredients, because starch has shown to cause detrimental health problems in sports horses. This study aimed at evaluating feeds considered to be suitable for horses by use of comprehensive carbohydrate analytical methods. Eighteen feeds of diverse botanical origin ranging from apple pulp, root crops, cereal grains and roughages were analysed for dry matter, ash, crude protein, fat, carbohydrates and lignin. Carbohydrates were analysed for sugar, starch, fructans, oligosaccharides and non-starch polysaccharides (NSP) using enzymatic-chemical methods and lignin by gravimetry. The results for total dietary fibre (DF) were compared with conventional crude fibre (CF) and neutral detergent fibre (aNDFom) methods. The physicochemical properties were quantified based on swelling and water binding capacity (WBC). Between 755 g and 970 g/kg DM was detected. The highest total sugar content was measured in root crops with 803 g/kg DM in raw sugar beet followed by 581 g/kg DM in carrots. The starch content ranged between 343 g/kg DM and 754 g/kg DM in cereal grains. The DF method detected ($P \leq 0.04$) more NSP as compared to the aNDFom and CF methods. The greatest difference between the DF and aNDFom methods was found in root crops and apple pulp in which the soluble non-cellulosic polysaccharides (S-NCP) fraction made up 350–581 g/kg of total NSP. The physicochemical properties were compared to fibre content and were associated to WBC ($P = 0.04$). The correlation ranged from 0.52 to 0.53 for WBC and from 0.03 to 0.16 for swelling. The S-NCP fraction is lost in the aNDFom and CF methods due to solubilisation, which explains the higher recovery of total NSP by the DF method. This illustrates that a feed's potential as a fibre source may be underestimated depending on the analytical method. Quantifying the soluble NCP fraction is beneficial as it has been shown to have health beneficial properties and contributes to the total energy supply. These results suggest that the DF method should be used when evaluating feeds for horses.

Abbreviations: ATP, adenosine triphosphate; DF, dietary fibre; GI, glycemic index; I-NCP, insoluble non-cellulosic polysaccharides; I-NSP, insoluble non-starch polysaccharides; NSP, non-starch polysaccharides; S-NCP, soluble non-cellulosic polysaccharides; S-NSP, soluble non-starch polysaccharides; SCFA, short chain fatty acids; WBC, water binding capacity; PCA, principal component analysis; CO, concentrate; FO, forages; RC, root crop and carrots; P', transposed loading matrix; $\mathbf{E_A}$, error matrix; N, number of samples; A, number of principal components; K, number of variables; $\mathbf{X}$, mean centred matrix; $\mathbf{T}$, score matrix.

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1. Introduction

The primary source of energy for hindgut fermenting herbivores like the horse is a wide range of carbohydrates, which broadly can be divided into two groups; those hydrolysed and absorbed in the small intestine, *i.e.* sugars and starch and those fermented in the hindgut, mainly fibre polysaccharides. The digestibility coefficient of unprocessed starch, varies from 0.90 in oats to as low as 0.30 in maize and 0.22 in barley due to limited α-amylase capacity, high pre-ceacal passage rate and chemical composition of different kinds of starch (Kienzle et al., 1992; Meyer et al., 1995). Starch is traditionally used to increase energy density in feed rations; however, over the past 20 years, several studies have shown that starchy meals can lead to decreased performance through insulin inhibited lipolysis (Stull and Rodiek, 1995; Lawrence et al., 1993), metabolic health problems (Kronfeld et al., 2005) and gastro intestinal dysfunction (Julliand et al., 2001). Horses have evolved to eat forages and therefore, the capacity to ferment fibrous material is highly developed as evidenced by plant cell wall digestibility coefficient of 0.44–0.77 depending on plant maturity (Ragnarsson and Lindberg, 2008). Acetate, a product of incomplete oxidation of fibre polysaccharides, is a metabolic precursor to acetyl CoA in the metabolism of carbohydrates and fats to produce adenosine triphosphate (ATP). According to Waller et al. (2009) oral acetate supply is a potential energy source for sports horses to replenish muscle glycogen. Therefore, fibrous feed can potentially increase the overall energy status of sports horses and replace the use of starch. The primary sources of fibre are plant cell walls, which differ in composition but contain up to 950 g/kg DM of various polysaccharides. The chemical determination of fibre therefore requires a procedure, which is capable of measuring a wide range of polysaccharides. The fibre content of a feed is defined by the method applied for its analysis, *i.e.* crude fibre (CF) (Henneberg and Stohmann, 1859), neutral detergent fibre (aNDFom) (Van Soest et al., 1991) and dietary fibre (DF) (Trowell et al., 1976). The analytical method for DF divides total non-starch polysaccharides (NSP) into soluble and insoluble NSP according to Bach Knudsen (1997). Plants generally contain a mixture of both soluble and insoluble NSP in a ratio that varies according to the type of plant and stage of maturity (Bach Knudsen, 1997). It is therefore hypothesised that an enzymatic-chemical DF method would provide more conclusive information on the nutritional properties of feed ingredients than conventional methods, based on theoretical knowledge of the equine alimentary tract.

The objectives of the current study was to evaluate feeds of different botanical origin by comprehensive carbohydrate analyses, characterise their physiochemical properties and compare results from the dietary fibre analyses with those obtained by the conventional crude fibre and neutral detergent fibre analyses.

2. Materials and methods

2.1. Materials

A total of 18 feeds of diverse botanical origin and representing various ingredients used in diets for horses were analysed. Apple pulp, maize, maize flakes, malt barley, apple syrup and commercial muesli feed (Equigard®, a loose chaff based concentrate composed of 240 g/kg grass hay, 220 g/kg apple pulp, 220 g/kg sugar beet pulp (SBP), 47 g/kg linseed, 35 g/kg linseed- and sunflower oil) was obtained from Mühle Ebert Dielheim Gmbh, Dielheim, Germany. The apple pulp is a co-product from juice production after a single squeeze and the residue is dried to 0.5 cm long pulps. The syrup is made from apples, where the juice is extracted and syrup is made by means of heating (Mühle Ebert Dielheim Gmbh, Dielheim, Germany). Maize flakes are produced by a technique that uses humidity and short term, high temperature followed by mechanical flaking and cooling to achieve a high level of starch gelatinisation (Mühle Ebert Dielheim Gmbh, Dielheim, Germany). Molassed sugar beet pulp; MSBP (Betfor®, 1.5 cm long pulps) and pelleted sugar beet pulps (SBP, 1 cm diameter) were obtained from Nordic Sugar A/S, Denmark. Sugar is extracted from whole sugar beets at 70 °C and the residue is dried to pulps. Betfor® differs from pelleted sugar beet pulp by the content of sprayed on sugar beet molasses. PreAlpin (PreAlpin Wiesencobs, Agrobs Gmbh, Münsing, Germany) consists of 40 g/kg forbs and 950 g/kg grasses and is artificially dried at 300 °C. The nutrient contents of the forbs and grasses are analysed before they are mixed to the specific product and pressed into cubes of 2 cm diameter. Unchopped barley straw was sun dried and baled in round bales, unchopped rye grass hay is a grass mix (Crop-mix number 50, Hunsballe Frø A/S, Holstebro, Denmark) consisting of 650 g/kg rye grass (*Lolium perenne*), 200 g/kg meadow-grass (*Poa pratensis*), and 150 g/kg timothy (*Phleum pratense*), sun dried and then baled in round bales and wrapped with 8 layers of 750 mm wide and 0.025 mm thick white or green stretch film (Silotite, bpi. agro, Herefordshire, UK) with 500 g/kg overlap. Unchopped grass/forbs hay (the seed mix consisted of 860 g/kg grasses, 140 g/kg forbs and legumes and was supplied by Olssons Frö AB, Helsingborg, Sweden) was sun dried, and then baled in big bales and wrapped with 10 layers of white stretch film (Silotite, bpi.agro, Herefordshire, UK) with 500 g/kg overlap. Lucerne hay was cut to 6 cm and artificially dried at 600 °C and then baled in big bales (DanGrønt Speciality Feeds, Ølgod, Denmark). Rye grass hay and lucerne were first cut, early stage pre-bloom. Grass/forbs hay was first cut, mature hay. The roughages were grown and preserved locally in Jutland, Denmark with the intention of being used as feed for horses. Timothy hay was sun dried and baled in round bales. It was first cut, pre-bloom and grown in Ås, Norway. Whole oats and barley, raw sugar beet (SB) and carrots were obtained from a feedstuff supplier (L H Foder, Sabro, Denmark). All samples were milled in a cutting mill to pass a 0,5 mm screen and stored at room temperature until analysis. Raw sugar beets and carrots were freeze-dried before milling.