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Effect of two methods of Van Soest fibre detergent system on monosaccharide compositions of acid detergent residues*

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ABSTRACT

This study was conducted to investigate the effect of sequential and direct detergent methods on the monosaccharide composition of acid detergent residues in three fibrous feedstuffs (lignified, highly digestible and highly pectic). The result indicated that the contents of ADF and cellulose determined by the sequential detergent method were lower than those determined by the direct detergent method ($P<0.05$). Compared with the direct detergent method, the sequential detergent method had lower content of each hemicellulosic monosaccharide contaminations, including xylose, mannose, arabinose and galactose ($P<0.05$). Based on the present data, the sequential detergent method should be recommended in regular laboratory analysis of fibrous feedstuffs for effective removing contaminated hemicellulose sugar units.

KEY WORDS: monosaccharide, Van Soest detergent fibre system, sequential detergent method, direct detergent method, fibrous feedstuffs

INTRODUCTION

Polysaccharide components of plant cell walls are important sources of energy for ruminant animals and play a key role in digestive regulation (Morrison, 1980). The significance of the precise and sensitive methods of analysis of plant cell walls has been long recognized. Detergent method, developed by Van Soest (1963), is an acknowledged analytic method of fibre determination in the plant material. There are two routine analyses for ADF determination: the sequential one, in which ADF

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is obtained from washing of the residual NDF fraction; and the direct one, in which feedstuffs samples are directly washed with the acid detergent (Van Soest and Jones, 1968). Differences in the ADF content between the two methods were found (Morrison, 1980; Robertson and Van Soest, 1981; Rebolé et al., 1989, 1990; Hintz et al., 1996; Mertens, 2003). Morrison (1980) considered that some contaminations of hemicellulose (HCE) were usually present in acid detergent residue (ADR). The major contaminations of ADR are monosaccharides (Morrison, 1980; Jung, 1997). However, any quantitative information is lacking regarding the kind and content of ADR monosaccharides between the sequential and direct detergent methods.

The purpose of the present study was to compare the difference of ADF and cellulose contents between the sequential and direct detergent methods. The kinds and the contents of some monosaccharides in residing ADR of three sources of fibrous feedstuffs were also determined by ion chromatography (IC) to offer quantitative information regarding their difference between the two detergent methods.

MATERIAL AND METHODS

Three different sources of fibrous feedstuffs, i.e. lignified, high digestible and high pectic, were selected. Lignified feedstuffs were wheat straw, rice straw and naked oat grass, maize stalks and high oil maize stalk, two maize silages, Chinese rye-grass hay, apple pomace and apple skin pellet. Highly digestible feedstuffs were soyabean hulls, soyabean hulls pellet and dehydrated distiller's grains (DDGS). Highly pectic feedstuffs were lucerne hay and lucerne pellet. Six replicates of each feedstuff sample were analysed in this study. All samples were ground to pass a 1 mm screen with a Wiley mill (Perten Laboratory Mill, Model 3100, Perten Equipment Inc., Sweden).

Fibre analyses, both sequential and direct, followed the procedures of Goering and Van Soest (1970) and Van Soest et al. (1991). Moreover, the samples of wheat straw, soyabean hulls and lucerne hay were used to determine the content of monosaccharides in ADR obtained by two detergent methods.

The hydrolytic procedure of the sample pre-treatment was performed according to Bourquin et al. (1990). The kind and the content of the monosaccharides were determined using IC (Dionex, Model ICS 2500 with CarboPac PA20 Column and Ampere Detector) under the following conditions: 5 mM NaOH for wheat straw, 2 mM and 10 mM NaOH for soyabean hulls and lucerne hay, constant flow rate at 0.38 ml/min and 25 µl injecting sample. A solution containing 25 mg/l of inositol used as an internal standard and fucose (Fuc, Sigma F-2252), arabinose (Ara, Fluka 10840), galactose (Gal, Amresco 0637), glucose (Glc, Sigma G-8270), mannose (Man, Sigma M-4319), rhamnose (Rha, Novachemo) or xylose (Xyl, Sigma X-3877), was used as the calibration standard. The amount of each monosaccharide was calculated

basying on its peak area percentage over the reference standard areas calibrated by an adjusting factor obtained from reference monosaccharide standards.

The experiment was subjected to statistical analysis in a factorial randomized design with six replicates of each sample by SAS (SAS, 1999). Analyses of variance (ANOVA) with mean comparisons using *t*-test were performed according to the GLM procedure.

RESULTS AND DISCUSSION

ADF and cellulose contents in feedstuffs determined by two methods are presented in Table 1. In most feedstuffs, the contents of ADF and cellulose determined by the sequential detergent method were lower than those determined by the direct detergent method ($P<0.05$). The contents of ADF and cellulose determined by the sequential method were usually less than those by the direct method, because neutral detergent could remove some components that were not removed as well by acid detergent (Hintz et al., 1996; Mertens, 2003).

Table 1. The contents of ADF and cellulose in feedstuffs determined by two methods

Feedstuff	ADF, g kg^{-1}		Cellulose [3], g kg^{-1}	
	d [1]	s [2]	D	s
Lignified feedstuff				
wheat straw	520.8 ± 5.1^{a}	476.0 ± 4.5^{b}	441.5 ± 2.9^{a}	396.8 ± 6.7^{b}
apple pomace	529.8 ± 9.5^{a}	458.4 ± 1.7^{b}	394.1 ± 7.3^{a}	325.9 ± 4.5^{b}
apple skin pellet	461.6 ± 10.2^{a}	405.4 ± 8.4^{b}	371.8 ± 8.1^{a}	320.4 ± 6.9^{b}
maize silage, Beijing	459.2 ± 10.2^{a}	369.0 ± 8.5^{b}	386.8 ± 8.6^{a}	300.4 ± 7.9^{b}
maize silage, Hebei	391.3 ± 13.7^{a}	349.4 ± 7.6^{b}	323.8 ± 9.4^{a}	284.7 ± 9.7^{b}
high oil maize stalk	347.3 ± 2.6^{a}	289.6 ± 4.5^{b}	305.1 ± 2.8^{a}	247.9 ± 12.1^{b}
maize stalk	513.1 ± 3.6^{a}	486.4 ± 7.5^{b}	438.4 ± 6.8^{a}	412.8 ± 9.6^{b}
Chinese rye-grass hay	385.2 ± 9.6^{a}	369.1 ± 6.3^{a}	312.2 ± 14.0^{a}	298.8 ± 6.7^{a}
rice straw	316.3 ± 1.6^{a}	287.4 ± 5.2^{b}	253.5 ± 3.9^{a}	224.0 ± 6.9^{b}
naked oats grass	373.7 ± 9.4^{a}	299.7 ± 8.6^{b}	298.0 ± 8.7^{a}	226.3 ± 8.6^{b}
High digestible feedstuff				
soyabean hulls	502.1 ± 0.3^{a}	462.1 ± 0.2^{b}	484.1 ± 8.9^{a}	444.1 ± 5.6^{b}
soyabean hulls pellet	497.8 ± 3.5^{a}	457.8 ± 2.9^{b}	482.8 ± 4.5^{a}	442.8 ± 1.7^{b}
DDGS	280.0 ± 3.0^{a}	216.0 ± 8.1^{b}	227.0 ± 1.3^{a}	168.8 ± 7.0^{b}
High pectic feedstuff				
lucerne hay	475.2 ± 2.0^{a}	434.5 ± 2.5^{b}	396.7 ± 1.4^{a}	355.3 ± 6.4^{b}
lucerne pellet	405.1 ± 1.2^{a}	370.1 ± 3.8^{b}	354.5 ± 1.9^{a}	323.1 ± 5.5^{b}
Mean	430.6	382.1	364.7	318.1

[1] d - the direct detergent method; [2] s - the sequential detergent method; [3] cellulose - ADF - ADL; [a, b] mean with different superscripts of letters in the same row differ significantly at $P<0.05$
DDGS - dehydrated distillers grains (maize) with solubles

As a result, some residing monosaccharides in hemicellulose still exist to some extent in ADR fractions after treatment by the direct detergent method. Morrison (1980) claimed that the reasons for the hemicellulosic contaminations associated with the direct detergent method are numerous, but it does seem to be directly related to the original content of lignin and phenolic acids in the plant materials. The most likely explanation by Morrison (1980) is areas of the polysaccharides covalently bound to the lignin and phenolic acids somehow become resistant to hydrolysis of acid detergent. However, it was yet unclear if monosaccharides in hemicellulose are involved in ADR fractions from the sequential detergent method and what kinds and amounts are.

Table 2. Profile of monosaccharide in ADR of three sources of feedstuffs from two detergent methods

Feedstuff	Profile of monosaccharide [6] in ADR, g kg $^{-1}$	
	d[1]	S[2]
Lignified feedstuff [3]		
Ara	1.0 ± 0.0[a]	0.5 ± 0.0[b]
Gal	0.4 ± 0.0[a]	ND[b] [7]
Glc	338.0 ± 2.0	331.4 ± 0.2
Xyl	69.8 ± 0.3[a]	43.5 ± 0.1[b]
Man	ND	ND
total	409.2	375.4
Highly digestible feedstuff [4]		
Ara	0.5 ± 0.0[a]	0.4 ± 0.0[b]
Gal	0.6 ± 0.0	0.5 ± 0.0
Glc	352.7 ± 1.0	354.2 ± 1.2
Xyl	60.1 ± 0.2[a]	43.8 ± 0.1[b]
Man	33.2 ± 0.1[a]	31.2 ± 0.1[b]
total	447.1	430.1
Highly pectic feedstuff [5]		
Ara	ND	ND
Gal	0.9 ± 0.0[a]	0.5 ± 0.1[b]
Glc	310.2 ± 7.0	296.8 ± 1.0
Xyl	45.8 ± 0.1[a]	30.4 ± 0.1[b]
Man	20.5 ± 0.2[a]	12.5 ± 0.1[b]
total	377.4	340.2

[1] d - direct detergent method; [2] s - sequential detergent method; [3, 4, 5] wheat straw, soyabean hulls and lucerne hay of original feedstuff materials are used as lignified, highly digestible and highly pectic feedstuff source, respectively; [6] Ara - arabinose, Gal- galactose, Glc - glucose, Xyl - xylose, Man - mannose; [7] ND - no detected; [a, b] mean with different superscripts of letters in the same row differ significantly at $P<0.05$

The major monosaccharide compositions of ADR of the three sources of feedstuffs are shown in Table 2. The minor content of remaining arabinose and galactose in ADR indicated that most hemicellulosic monosaccharides in the sample were removed by acid detergent in both detergent methods. However, ADR contains a relatively higher amount of xylose and mannose in the direct method than the sequential method no matter what types of feedstuffs were determined.

The total monosaccharide contents in ADR varied between the two detergent methods. According to the gravimetric procedure, cellulose was estimated by subtraction of ADL from ADF, and therefore, all sugar units theoretically present in ADR were glucose from hydrolyzation of cellulose. Based on the result showed in Table 2, either detergent method overestimated the amount of cellulose because of contaminated hemicellulosic monosaccharides. Furthermore, the contents of total monosaccharide derived from ADR in the sequential method were lower than those in the direct method. This result is consistent with that of Morrison (1980) and Jung (1997).

In this study, the hemicellulosic monosaccharide contaminations in ADR indicated that both the detergent methods failed to remove all hemicellulose (HCE). The reason may attribute to the interference of the pectic substances and the phenolic acid complex. However, compared with the direct detergent method, the sequential detergent method had lower content of each hemicellulosic monosaccharide contaminations ($P<0.05$). The reason seems to be related to dissolution of some HCE in pectic substances by neutral detergent. These explanations were also supported by previous studies (Morrison, 1980; Hintz et al., 1996; Mertens, 1996; Hindrichsen et al., 2006).

CONCLUSIONS

The sequential detergent method is superior to the direct detergent method on fibre analysis. ADF and cellulose contents of the fibrous feedstuffs account for the difference between the two methods. The sequential detergent method had effective analysis for ADF and cellulose contents. A relatively large amount of xylose and mannose contaminations in acid detergent residue by the direct detergent method rather than the sequential one would be accountable for the difference between two methods in three sources of feedstuffs.

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