

Postprint of a Study on the Components in Feed Crude Fiber, Neutral Detergent Fiber, and Acid Detergent Fiber Residues

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Abstract

This experiment aimed to investigate the various components in crude fiber (CF), neutral detergent fiber (NDF), and acid detergent fiber (ADF) residues of feeds. The polyester fiber mesh bag method was used to determine the CF, NDF, and ADF contents of 18 feedstuffs including rice bran, wheat bran, white clover, paper mulberry leaves, whole-plant corn, whole-plant wheat, hairy vetch, rabbit compound feed, sorghum, oat straw, alfalfa, rice straw, triticale hay, king grass, reed, peanut vine, soybean straw, and rice husk powder. The contents and recovery rates of hemicellulose, cellulose, acid detergent lignin, and acid-insoluble ash in CF residues were determined, while the contents of these components in NDF and ADF residues were also measured. The study investigated the component profiles of CF, NDF, and ADF residues and the relationships between CF and ADF. The results showed that cellulose exhibited the highest recovery rate in CF residues among the 18 tested feedstuffs (71.28%~105.03%). A highly positive correlation was observed between feed ADF content (y_1) and CF content (x_1): $y_1=1.5071+1.2115x_1$ ($r=0.9792$, $RSD=1.8634$, $P<0.01$). An even stronger correlation was found between ADF content after removal of acid-insoluble ash from ADF residues (y_2) and CF content (x_2): $y_2=2.4063+1.0770x_2$ ($r=0.9905$, $RSD=0.9624$, $P<0.01$). Based on these findings, an accurate calculation method for determining hemicellulose and cellulose contents in feeds was proposed, i.e., hemicellulose content equals NDF content (without acid-insoluble ash) minus ADF content (without acid-insoluble ash); cellulose content equals ADF content (without acid-insoluble ash) minus acid detergent lignin content.

Full Text

Study of Components in Residue of Crude Fiber, Neutral Detergent Fiber and Acid Detergent Fiber in Feed

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Abstract: This experiment was conducted to investigate the components in residues of crude fiber (CF), neutral detergent fiber (NDF), and acid detergent fiber (ADF) in feed. The polyester fiber mesh bag method was used to determine the CF, NDF, and ADF contents of 18 feed types: rice bran, wheat bran, white clover, citron leaves, whole corn, whole wheat, *Vicia villosa*, rabbit feed, sorghum, oat straw, alfalfa, rice straw, triticale hay, *Pennisetum hybridum*, reed, peanut seedling, soybean stalk, and rice husk powder. The content and recovery rate of hemicellulose, cellulose, acid detergent lignin (ADL), and acid insoluble ash (AIA) in CF residue were measured, while the contents of these components in NDF and ADF residues were also determined. The study examined the composition of CF, NDF, and ADF residues and the relationship between CF and ADF. The results showed that cellulose in the 18 tested feeds had the highest recovery rate in CF residue (71.28%-105.03%). A highly positive correlation was observed between feed ADF content (y) and CF content (x): $y = 1.5071 + 1.2115x$ ($r = 0.9792$, $RSD = 1.8634$, $P < 0.01$). An even stronger correlation was found between ADF content after AIA removal (y) and CF content (x): $y = 2.4063 + 1.0770x$ ($r = 0.9905$, $RSD = 0.9624$, $P < 0.01$). Based on these findings, we propose accurate calculation methods for hemicellulose and cellulose contents: hemicellulose content equals NDF content (without AIA) minus ADF content (without AIA), and cellulose content equals ADF content (without AIA) minus ADL content.

Key words: crude fiber; neutral detergent fiber; acid detergent fiber; acid detergent lignin

Crude fiber (CF) content in feed has been widely used as a guaranteed value in product composition analysis for feed ingredients and compound feed product labels [?]. Feed CF refers to the insoluble organic matter remaining after feed is treated with dilute acid and dilute alkali, including cellulose (CEL), hemicellulose (HCEL), acid detergent lignin (ADL), and a small amount of acid insoluble ash (AIA). During the acid-alkali boiling process for CF determination, various fiber components may be partially decomposed, raising questions about their content and recovery rates in CF residue. Van Soest et al. [?] proposed methods for determining neutral detergent fiber (NDF), acid detergent fiber (ADF), and ADL contents, which have been widely adopted, and China has established corresponding national and industry standards [?, ?, ?]. With improvements

in feed NDF, ADF, and ADL determination methods, analytical efficiency has been significantly enhanced [?, ?], and these indicators are increasingly applied in feed nutritional value evaluation [?, ?, ?]. However, research on the composition of components in feed NDF and ADF residues remains limited.

This study selected 18 representative fiber-rich feed and forage samples, including rice bran, wheat bran, white clover, and others, to analyze CF, NDF, ADF, and ADL contents. The contents of HCEL, CEL, ADL, and AIA in CF, NDF, and ADF residues were determined to investigate the relationship between feed ADF and CF contents, providing a theoretical basis for evaluating feed nutritional value using CF, NDF, ADF, and ADL indicators.

1.1 Experimental Materials

Eighteen representative fiber-rich feed and forage samples were selected: rice bran, wheat bran, white clover, citron leaves, whole corn, whole wheat, *Vicia villosa*, rabbit feed, sorghum, oat straw, alfalfa, rice straw, triticale hay, *Penisetum hybridum*, reed, peanut seedling, soybean stalk, and rice husk powder. These were prepared as semi-dry or air-dry laboratory samples, processed according to GB/T 20195-2006 [?], ground to pass through a 1.00 mm metal sieve, thoroughly mixed, and stored in sealed containers for analysis. All measurements were performed in duplicate for each sample.

1.2 Measurement Methods

The polyester fiber mesh bag method was used to determine feed CF, NDF, ADF, and ADL contents [?, ?, ?]. For determining components in feed CF residue, four parallel samples of each feed were prepared. After CF content determination, the four mesh bags containing residues were used as follows: two bags for measuring AIA content in CF residue, and the other two for measuring HCEL, CEL, and ADL contents in CF residue. The calculation formulas were:

$$\begin{aligned} \text{HCEL content in CF residue (\%)} &= \text{CF content in feed} - \text{ADF content in feed} \\ \text{CEL content in CF residue (\%)} &= \text{ADF content in feed} - (\text{ADL content in feed} \\ &+ \text{AIA content in feed}) \\ \text{ADL content in CF residue (\%)} &= (\text{ADL content in feed} + \text{AIA content in feed}) \\ &- \text{AIA content in CF residue} \end{aligned}$$

Recovery rates of components in CF residue were determined by first measuring the content of each component in the feed, then measuring its content in CF residue. The recovery rate was calculated as the percentage of a component's content in CF residue relative to its content in the feed:

$$\begin{aligned} \text{HCEL recovery in CF residue (\%)} &= (\text{HCEL content in CF residue} / \text{HCEL} \\ &\text{content in feed}) \times 100 \\ \text{CEL recovery in CF residue (\%)} &= (\text{CEL content in CF residue} / \text{CEL content} \\ &\text{in feed}) \times 100 \end{aligned}$$

ADL recovery in CF residue (%) = (ADL content in CF residue / ADL content in feed) \times 100

1.3 Statistical Analysis

Experimental data were organized and analyzed using Excel 2010, with results expressed as mean values.

2.1 Fiber Component Contents in Feed

As shown in Table 1, among the 18 feeds, NDF content ranged from 23.96% to 82.74%, ADF content from 9.38% to 66.48%, HCEL content from 10.09% to 29.67%, CEL content from 7.03% to 41.73%, and ADL content from 0.87% to 24.75%, indicating substantial variation in fiber component contents among different feeds.

2.2 Fiber Component Contents and Recovery Rates in CF Residue

Table 2 shows that CF content (without AIA) in feeds ranged from 8.05% to 47.90%. CF residue was primarily composed of CEL (5.59%–36.65%), with small amounts of HCEL (1.18%–4.60%), ADL (0.00%–7.75%), and AIA (0.21%–2.53%). The ADL content in CF residue was related to the ADL content in the original feed, with higher values observed in alfalfa, peanut seedling, soybean stalk, and rice husk powder.

Cellulose exhibited the highest recovery rate in CF residue, ranging from 71.36% to 105.03%. For *Vicia villosa*, oat straw, rice straw, *Pennisetum hybridum*, whole corn, sweet sorghum, whole wheat, alfalfa, triticale hay, and reed, recovery rates were close to 100%, while other feeds showed CEL recovery rates between 71.26% and 88.96%. In contrast, HCEL and ADL recovery rates in CF residue were relatively low, ranging from 4.33% to 36.15% and 0 to 84.38%, respectively.

2.3 Fiber Component Contents in NDF and ADF Residues

As shown in Table 3, feed NDF residue primarily contained HCEL and CEL, along with ADL and AIA. The ADL content in NDF residue was 21.28% for rice husk powder and ranged from 1.77% to 10.97% for other feeds. Feed ADF residue was primarily composed of CEL, with ADL and AIA also present. AIA contents in NDF and ADF residues ranged from 1.00% to 9.53% and 0.26% to 10.36%, respectively, with rice straw and rice husk powder showing particularly high values.

2.4 Analysis of HCEL and CEL Content Calculation Methods

Traditional calculation of feed HCEL content uses: $(\text{HCEL}) = (\text{NDF}) - (\text{ADF})$. An alternative method calculates HCEL content using NDF and ADF contents after AIA removal: $(\text{HCEL}) = [\text{NDF (without AIA)}] - [\text{ADF (without AIA)}]$. A sequential method determines HCEL content as (HCEL) by first measuring

NDF content, then directly determining ADF content from the NDF residue. As shown in Table 4, (HCEL) and (HCEL) values were essentially identical, with a correlation coefficient of 0.9947. However, the sequential method yielded higher (HCEL) values with significant differences for some data points.

Feed CEL content was calculated using two methods: (CEL) = (ADF) - (ADL + AIA) and (CEL) = [ADF (without AIA)] - (ADL). As shown in Table 4, (CEL) values were higher than (CEL) values, with substantial differences for some feeds; for example, rice husk powder CEL contents were 41.73% and 31.37%, respectively.

2.5 Relationship Between Feed CF and ADF Contents

Regression analysis of the 18 feeds revealed a highly positive correlation between ADF content (y) and CF content (x): $y = 1.5071 + 1.2115x$ ($r = 0.9792$, $RSD = 1.8634$, $P < 0.01$). An even stronger correlation was observed between ADF content after AIA removal (y) and CF content (x): $y = 2.4063 + 1.0770x$ ($r = 0.9905$, $RSD = 0.9624$, $P < 0.01$), which can be used for estimation between the two parameters.

3.1 Factors Affecting Fiber Component Recovery in CF Residue

The recovery rates of HCEL, CEL, and ADL in feed CF residue are related to their chemical properties. After acid-alkali treatment, CF residue is primarily composed of CEL, with small amounts of HCEL, ADL, and AIA. During acid-alkali boiling, feed CEL, HCEL, and ADL may be partially dissolved. Cellulose is the most stable component, resistant to dilute acid and alkali boiling, resulting in high recovery rates in CF residue. Hemicellulose is unstable and soluble in dilute acid and alkali, leading to low recovery rates. Lignin is acid-resistant but largely dissolved during alkali boiling [?, ?]. This experiment demonstrated that recovery rates of fiber components in CF residue varied among different feeds due to differences in HCEL, CEL, and ADL composition and content.

3.2 Discussion of HCEL and CEL Measurement Methods

Since NDF and ADF are mixtures with variable component contents, indicators such as HCEL, CEL, and ADL content more clearly reflect feed fiber composition. AIA contents in feed NDF and ADF residues ranged from 1.00% to 9.53% and 0.26% to 10.36%, respectively—non-negligible levels. Therefore, we recommend that feed NDF and ADF content indicators should be designated as two separate metrics: NDF (with AIA) and NDF (without AIA), or ADF (with AIA) and ADF (without AIA).

The traditional method for determining feed HCEL content uses the difference between NDF and ADF contents. We propose that feed HCEL content should equal NDF (without AIA) content minus ADF (without AIA) content. Our results show that values obtained by these two methods are essentially identical ($r = 0.9947$), and both can be used to calculate feed HCEL content. However,

the latter method yields more accurate values by eliminating AIA interference from NDF and ADF. The sequential method, which determines HCEL content by first measuring NDF content then directly measuring ADF content from the NDF residue, produces overestimated HCEL values with significant differences for some data points. Therefore, the sequential method is unsuitable for feed HCEL determination.

For feed CEL content, the traditional calculation uses $(CEL) = (ADF) - (ADL + AIA)$, while we propose $(CEL) = [ADF \text{ (without AIA)}] - (ADL)$. The two methods produced different CEL values for some feeds, with the latter method providing more accurate results by eliminating AIA interference from ADF.

3.3 Relationship Between Feed CF and ADF Contents

Feed CF and ADF contents are closely related. Cellulose is the primary component of feed CF residue, accounting for an average of 79.91% of CF residue content in this study, with smaller amounts of HCEL and ADL also present. Similarly, CEL is the main component of feed ADF residue, representing an average of 77.35% of ADF residue content, along with all ADL and AIA. In this study, ADF content values were 128.96% of CF content values across the 18 feeds, with a high correlation coefficient of 0.9792.

After AIA removal, ADF (without AIA) content includes all CEL and ADL from the feed. The compositional difference between ADF (without AIA) and CF lies in the former containing all feed ADL while the latter contains only partial ADL; consequently, ADF (without AIA) content always exceeds CF content for the same feed. In this study, ADF (without AIA) content was 120.00% of CF content, with a high correlation coefficient of 0.9905 that can be used for estimation. We recommend using the ADF (without AIA) indicator instead of the CF indicator to evaluate CEL and ADL components in feed, as it is more accurate and easier to determine.

Conclusions

1. Cellulose in the 18 tested feeds showed the highest recovery rate in CF residue (71.28%-105.03%).
2. A highly positive correlation exists between feed ADF content (y) and CF content (x): $y = 1.5071 + 1.2115x$ ($r = 0.9792$, $RSD = 1.8634$, $P < 0.01$).
3. An even stronger correlation was observed between ADF content after AIA removal (y) and CF content (x): $y = 2.4063 + 1.0770x$ ($r = 0.9905$, $RSD = 0.9624$, $P < 0.01$).
4. Accurate calculation methods are proposed: hemicellulose content equals NDF (without AIA) content minus ADF (without AIA) content; cellulose content equals ADF (without AIA) content minus ADL content.

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