

Proximate analysis of fibres of grain sorghum, pearl millet and sesame residues and their fractions in Gadarif State, Sudan

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ABSTRACT

Proximate analysis and fibres were determined in different fractions of sorghum stover [*Sorghum bicolor* (L.) Moench.] (Arfaa gadamac variety), sesame straw (*Sesamum indicum* L.) and millet straw [*Pennisetum typhoides* (Burm.)] with roots or without roots in Gadarif State, Sudan, in 2007. The plants were divided into upper, middle and lower parts and leaves. There were great variations in the composition of the straws and their fractions and they had low crude protein (CP) and high fibre content. Sorghum stover had the highest CP, ash and nitrogen free extract (NFE) and the lowest crude fibres (CF) and modified acid detergent fibres (MADF) among the crop residues. Millet straw had the lowest ether extract (EE) and NFE and the highest neutral detergent fibres (NDF) and MADF. Crude fibre was not significantly ($P>0.05$) different in millet and sesame straws. Leaves had the highest CP and lowest fibre content. Crop residues nutritive value declined from the top to the bottom of the plants.

INTRODUCTION

Livestock production is very important in the Sudan due to high population, wide distribution and socioeconomic impacts (MARF, 2008). Animals are mainly reared in traditional systems based on nomadism and rangelands which deteriorated due to many reasons (Mohmed, 2001). Seasonal variations in rangeland plants quantity and quality are associated with seasonal rainfall which led to serious feed shortages in the long dry

season affecting livestock health and performance (Hamed, 2007). Rangeland provided about 74.7% of animal feeds in the Sudan and the gap is filled with agro industrial by-products, especially crop residues. About 19 million tons of crop residues are produced in the Sudan annually, forming about 22% of animal feeds in the country. However, crop residues generally have low nutritive value due to high fibres and low CP contents and mainly fed unimproved depressing dry matter intake (DMI) (Hamed, 2007). Physical procedures, including fractionations, are used to improve straws nutritive value and animals performance.

Crop residues vary in the composition of plants parts (Wang *et al.*, 2006). Crop residues structural carbohydrates and lignin may vary widely among parts and directly affect nutritive value or available energy (Van Soest, 1982). Nitrogen varied among straw fractions and ranged from 0.32% in stems to 0.91% in panicles in maize stover and 0.35% in stems to 5.7% in leaves of rice straw (Mgheni *et al.*, 2001). Nitrogen was higher in whole plants, leaves, leaf sheath and panicles and lower in stems of maize straw than rice straw. In whole plants NDF, acid detergent fibres (ADF) and acid detergent lignin (ADL) were higher in maize stover (74.7, 49.3 and 6.9, respectively) than rice straw (63.6, 42.1 and 4.6, respectively). It was found that CP and OM were similar in cereal straws and NDF, ADF and ADL were significantly affected by type of cereals. Wheat straw had significantly higher NDF and ADF than other cereals (Rahimi *et al.*, 2011). All *in vitro* gas production kinetics parameters were not significantly different among cereal straws. Gene mutant rice straw variety brittle culm1 had significantly lower ADF and ash and higher lignin and CP than the wild variety (Wang *et al.*, 2006). It also had significantly higher gas production rate and lower potential gas production and lag time than the wild variety. There were small differences in organic matter digestibility between the two varieties. Increasing the age at harvest increased lignin and decreased CP in the two varieties. Stem NDF was lower and gas production and OM digestibility were significantly higher than other fractions. Cereal straws and their fractions varied greatly in DM, protein free dry matter (PFDM) and N extent and rate of rumen degradation (Mgheni *et al.*, 2001).

Information on crop residues fractions percentages and nutritive value are scarce in Sudan. Consequently, this study was conducted to determine the chemical composition of grain sorghum, pearl millet and sesame straws.

MATERIALS AND METHODS

Study area

Sorghum stover [*Sorghum bicolor* (L.) Moench.] (Arfaa gadamac variety), sesame straw (*Sesamum indicum* L.) and millet straw [*Pennisetum typhoides* (Burm.)] samples were collected with roots from Gadarif University farm, Gadarif State, Sudan in 2007. Gadarif lies in the eastern part of the Sudan at latitudes 12° 40' - 15° 45' N and longitudes 33° 34' - 37° 1' E. The rainy season is from July to October and average annual rainfall is 602 mm. Average maximum temperature is 40°.7 in April 2007.

Sample collection and preparation

Each crop residue sample was divided into two parts. One part was fractionated into upper, middle and lower parts and leaves using cutters. The other part was divided into two divisions, one with roots and the other without roots. Sesame straw was fractionated into equal upper, middle and lower parts. The fractionated parts were stored and used for laboratory analysis. Treatments were arranged in a completely randomized design with three replicates.

Laboratory analysis

Crop residue fraction samples were ground and analysed in triplicates according to AOAC (1995). Neutral detergent fibre was conducted according to Goering and Van Soest (1970) and MADF was executed according to Van Soest procedure (1982).

Statistical analysis

Data were subjected to the analysis of variance procedure. Mean comparison was carried out using Scheff's test.

RESULTS

Table 1 shows great variations in proximate analysis and fibres among crop residues in Gadarif State. Ether extract and CP were generally low in all crop residues. Ether extract was significantly ($P < 0.05$) highest in sesame straw and lowest in millet straw. Crude protein was significantly ($P < 0.05$) higher in sorghum stover and millet straw than sesame straw. Crude fibre was generally higher in all crop residues and was significantly ($P < 0.05$) lower in sorghum stover. Ash was significantly higher ($P < 0.05$) in sorghum stover than sesame straw. Nitrogen free extract was significantly ($P < 0.05$) higher in sorghum stover than millet and sesame straws. There were significant variations ($P < 0.05$) in NDF and MADF among crop residues and were highest in millet straw. Neutral detergent fibre was low in sesame straw and MADF was low in sorghum stover. Sorghum stover had the highest DM, CP, ash and NFE and the lowest CF and MADF among crop residues. Millet straw had the lowest EE and NFE and the highest NDF and MADF.

Table 1. Chemical composition of sorghum stover (Arfaa gadamac) and millet and sesame straws (%DM) in Gadarif area, Sudan.

	DM	EE	CP	CF	Ash	NFE	NDF	MADF
Sorghum stover	97.53 ^a	1.27 ^b	5.72 ^a	30.44 ^b	11.13 ^a	51.44 ^a	73.00 ^b	33.50 ^c
Sesame straw	96.57 ^b	1.57 ^a	4.52 ^b	40.01 ^a	7.84 ^b	46.05 ^b	67.50 ^c	40.50 ^b
Millet straw	96.87 ^{ba}	0.50 ^c	5.21 ^a	39.99 ^a	10.80 ^a	43.50 ^b	79.00 ^a	52.50 ^a
Mean	96.99	1.11	5.15	36.81	9.92	47.06	73.175	42.17
S.E.(±)	0.175	0.162	0.191	1.621	0.534	1.231	1.704	2.778
C.V (%)	0.35	0.11	0.28	1.03	0.39	1.32	1.32	0.50

Means with different superscripts in the same column are significantly ($p < 0.05$) different according to Scheff's test. DM= Dry matter, CP= Crude protein, CF= Crude fibres, EE=Ether extract, NFE=Nitrogen free extracts, NDF= Neutral detergent fibres, MADF= Modified acid detergent fibres.

Table 2 shows the variations in proximate analysis and fibres in sorghum stover fractions. Dry matter content was generally very high in all parts with no significant ($P > 0.05$) differences among whole plant with roots (WP), whole plant without roots (WPO) and different fractions. Ether extract was generally low in WP and WPO and all fractions with no significant

differences between WP and WPO. It was significantly ($P < 0.05$) highest in leaves and lowest in the lower fraction. There were no significant differences ($P > 0.05$) among WP, WPO and fractions in CP and was highest in whole plants. Crude fibre was relatively lower in WPO than WP, but not significantly different ($P > 0.05$) and was lowest in the upper part, but was not significantly different ($P > 0.05$) from other fractions. Leaves had significantly ($p < 0.05$) the lowest CF compared to WP, WPO and fractions. Ash was significantly ($p < 0.05$) higher in WPO than WP and was not significantly different among parts. Whole plant without roots had significantly the highest ash compared to leaves and other fractions. There were no significant differences ($P > 0.05$) in NFE between WP and WPO or

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between upper, middle and lower parts. Leaves had significantly ($p < 0.05$) the highest NFE compared to WP, WPO and the fractions.

Table 2. The chemical composition of different fractions of sorghum stover (Arfaa gadamac) (% DM) in Gadarif area, Sudan.

	DM	EE	CP	CF	Ash	NFE	NDF	MADF
WP	97.53	1.27 ^{bc}	5.72	30.44 ^a	11.13 ^b	51.44 ^{cbd}	73.00 ^a	33.50 ^c
WPO	96.67	1.20 ^c	5.75	29.93 ^a	13.43 ^a	49.69 ^d	55.50 ^{cd}	39.00 ^b
Upper	96.90	1.37 ^{bc}	5.19	29.89 ^a	10.31 ^b	53.24 ^{cb}	60.50 ^b	35.50 ^c
Middle	96.83	1.43 ^{bc}	5.15	32.00 ^a	11.15 ^b	50.27 ^{cd}	59.00 ^{cb}	39.50 ^b
Lower	95.33	0.80 ^d	5.18	30.00 ^a	10.30 ^b	53.73 ^b	59.00 ^{cb}	44.00 ^a
Leaves	97.60	1.60 ^a	5.60	20.43 ^b	10.57 ^b	61.80 ^a	51.50 ^a	30.00 ^d
Mean	96.81	1.28	5.43	28.78	11.15	53.36	59.75	36.92
S.E.(+)	0.295	0.061	0.096	0.936	0.273	1.001	1.633	1.105
C.V(%)	1.170	0.060	0.350	0.780	0.870	1.150	6.110	1.980

Means with different superscripts in the same column are significantly ($p < 0.05$) different according to Scheff's test.

WP = Whole plant with roots, WPO = Whole plant without roots, Upper = Upper part of plants, Middle = Middle part of plants, Lower = Lower part of plants.

DM= Dry matter, CP= Crude protein, CF= Crude fibres, EE= Ether extract, NFE= Nitrogen free extracts, NDF= Neutral detergent fibres, MADF= Modified acid detergent fibres.

Neutral detergent fibre was significantly ($P < 0.05$) higher in WP compared to WPO and was not significantly different ($P > 0.05$) among upper, middle and lower parts. Leaves had significantly ($P < 0.05$) the lowest NDF compared to WP and fractions. Modified acid detergent fibre was significantly ($P < 0.05$) higher in WPO compared to WP and significantly ($P < 0.05$) increased from the upper to the lower parts. Leaves had significantly ($P < 0.05$) the lowest MADF. The plant with roots had higher DM, EE, CF, NFE and NDF and lower MADF, CP and ash than WPO. The lower part had the highest MADF. Leaves had the highest EE and NFE and lowest CF, NDF and MADF among parts.

There were generally great variations in proximate analysis and fibres among millet straw parts (Table 3). Ether extract was generally low with no significant differences between WP and WPO and was significantly ($P < 0.05$) higher in the upper part compared to middle and lower parts. Leaves EE was close to the upper part and was significantly ($P < 0.05$) higher than WP, WPO and middle and lower parts. Crude protein was generally low in different fractions and was significantly ($p < 0.05$) higher in WPO compared to WP. It was not significantly different ($P > 0.05$) among upper, middle and lower parts. Leaves CP was similar to WPO and significantly ($P < 0.05$) higher than WP and other fractions. Crude fibre was generally high in different parts and was relatively low in WPO than WP, but not significantly. The upper part had the lowest CF among parts and was significantly ($P < 0.05$) different from the lower one. Leaves had significantly ($P < 0.05$) the lowest CF compared to WP, WPO and fractions. Crude fibre generally increased from the upper to the lower part. Ash significantly varied ($P < 0.05$) among parts and was significantly ($P < 0.05$) higher in WPO than WP.

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It was not significantly different among upper, middle and lower parts and was significantly ($P < 0.05$) higher in WP and WPO than leaves and other parts. There were no significant differences in NFE between WP and WPO. It generally decreased from the upper to the lower part with no significant differences between upper and middle parts. Leaves had significantly ($P < 0.05$) higher NFE than WP, WPO and parts.

Neutral detergent fibre and MADF were significantly ($P < 0.05$) highest in WP than WPO and significantly ($P < 0.05$) increased from the upper to the lower part. Whole plant with roots and the lower part had similar and significantly ($P < 0.05$) the highest NDF than WP, upper, middle part and leaves. Leaves and the upper part had the lowest NDF. The upper part had significantly ($P < 0.05$) the lowest MADF than middle and lower parts which were not significantly different. Leaves had significantly ($P < 0.05$) the lowest MADF compared to WP, WPO and the fractions. Whole plant without roots had higher CP and ash and lower CF, NDF and MADF.

The lower part had lower EE, NFE and the highest CF, ash, NDF and MADF. Leaves had the highest CP, NFE and the lowest CF, NDF and MADF.

Table 3. The chemical composition of different fractions of millet straw (% DM) in Gadarif area, Sudan.

	DM	EE	CP	CF	Ash	NFE	NDF	MADF
WP	96.87	0.50 ^{ba}	5.21 ^b	39.99 ^a	10.80 ^b	43.50 ^{ed}	79.00 ^a	52.33 ^a
WPO	97.30	0.40 ^b	6.42 ^a	37.22 ^{ba}	13.42 ^a	42.54 ^e	67.00 ^c	38.00 ^b
Upper	97.57	1.03 ^a	4.42 ^b	35.77 ^b	6.87 ^{dc}	51.91 ^b	53.00 ^d	40.00 ^b
Middle	97.07	0.40 ^b	4.14 ^b	39.00 ^{ba}	6.70 ^d	49.76 ^{cb}	75.00 ^b	50.00 ^a
Lower	97.83	0.40 ^b	4.71 ^b	41.11 ^a	7.50 ^{dc}	47.28 ^{cd}	78.00 ^a	51.00 ^a
Leaves	98.10	0.97 ^a	6.61 ^a	27.33 ^c	8.17 ^c	56.92 ^a	52.33 ^d	32.00 ^c
Mean	97.46	0.62	5.25	36.57	8.91	48.65	67.39	43.89
S.E.(±)	00.152	0.075	0.242	01.088	0.596	01.225	02.695	01.861
C.V(%)	00.56	0.17	0.54	01.36	00.97	01.32	04.12	04.94

Means with different superscripts in the same column are significantly ($p < 0.05$) different according to Scheff's test. WP = Whole plant, WPO = Whole plant without roots, Upper = Upper part of plants, Middle = Middle part of plants, Lower = Lower part of plants, DM= Dry matter, CP= Crude protein, CF= Crude fibres, EE= Ether extract, NFE= Nitrogen free extracts, NDF= Neutral detergent fibres, MADF= Modified acid detergent fibres.

Table 4 shows the proximate analysis and fibres in different parts of sesame straw. Ether extract was generally low in sesame straw and different parts and decreased from the upper to the lower part and was significantly ($P < 0.05$) lowest in the lower part than WP and parts. Crude protein was generally low in sesame straw and fractions and decreased from the upper to

the lower part. It was significantly ($P < 0.05$) highest in the upper part and lowest in the lower part. Crude fibre varied significantly ($P < 0.05$) among sesame straw and fractions. It was significantly

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($P < 0.05$) increased from the upper to the lower part and the latter had significantly ($P < 0.05$) the highest CF. Ash was significantly ($P < 0.05$) low in the lower part than WP and other fractions and was not significantly different ($P > 0.05$) between WP and parts. Nitrogen free extract was significantly ($P < 0.05$) highest in the upper part compared to whole plant and other parts and significantly ($P < 0.05$) decreased from the upper to the lower part.

Table 4. The chemical composition of different fractions of sesame straw (% DM) in Gadarif area, Sudan.

	DM	EE	CP	CF	Ash	NFE	NDF	MADF
WP	96.57	1.57 ^a	4.52 ^{bc}	40.01 ^b	7.84 ^a	46.05 ^{cb}	67.50 ^a	40.50 ^c
Upper	97.63	1.47 ^a	5.45 ^a	33.40 ^d	7.99 ^a	51.61 ^a	59.00 ^b	45.00 ^{cb}
Middle	95.90	1.43 ^a	5.24 ^{ba}	37.33 ^c	7.48 ^a	48.51 ^b	59.50 ^b	45.50 ^b
Lower	96.83	0.93 ^b	4.34 ^c	43.61 ^a	7.57 ^b	44.54 ^c	66.50 ^a	59.50 ^a
Mean	96.33	1.35	4.91	38.59	7.47	47.68	63.13	47.63
S.E.(±)	00.141	0.085	0.164	1.145	0.178	00.839	01.186	02.186
C.V(%)	00.45	0.17	0.28	0.84	0.25	00.94	00.66	01.64

Means with different superscripts in the same column are significantly ($p < 0.05$) different according to Scheff's test. WP = whole plant, Upper = Upper part of plants, Middle = Middle part of plants, Lower = Lower part of plants. DM= Dry matter, CP= Crude protein, CF= Crude fibres, EE= Ether extract, NFE= Nitrogen free extracts, NDF= Neutral detergent fibres, MADF= Modified acid detergent fibres.

Neutral detergent fibre was significantly ($P < 0.05$) highest in the WP and the lower part than the upper and middle parts. It was not significantly different between upper and middle parts. Modified acid detergent fibre was significantly ($P < 0.05$) higher in the lower part than WP and parts. It was not significantly different between upper and middle parts.

Generally, in all crop residues leaves had the lowest fibres (CF, NDF and MADF) and the lower part had the highest fibres (CF, NDF and MADF) compared to other parts. Ether extract, CP, ash and NFE decreased from the upper to the lower part. Crude fibre, NDF and MADF increased from the top to the bottom of the plant.

DISCUSSION

The variations in proximate analysis and fibres among straws in this study were reported by many workers (Adebowale, 1988, Wang *et al.*, 2006, Rahimi, 2011). The variations in proximate analysis and fibres among straws in this study were mainly genetical and/or due to environmental factors (Adebowale, 1988). The high DM in all crop residues straws was similar to that found by Abusail (1992) and was due to maturity and decreased moisture with age (McDonald *et al.*, 1994). In addition,

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the crop residues were sun cured. The low EE and CP in straws in this study were reported by many workers (McDonald *et al.*, 1994, Sulieman and Abdelrahim, 1999) and was attributed to plant maturity and nutrients transfer from stems and leaves to grains. Ether extract in sorghum stover was similar to that found by Mohamed (1988) and Sulieman and Abdelrahim (1999) and lower than that found by Abuhatab (1988). The relatively high EE in sesame straw may be due to sesame capsules and seeds which are higher in EE. Sorghum stover CP was similar to the findings reported by Osman (1985) and Mohamed (1988) and higher than that found by Elhag (1984). The crude protein, EE and CF in millet straw were lower than that reported by Abusail (1992). The high CF in the three straws confirmed the results of many workers (Mohamed, 1988, Ibrahim, 1998) and was due to plants maturity and high fibres and lignification (Van Soest, 1982). Crude fibre in sorghum stover was similar to that reported by Mohamed (1988), higher than that found by Osman (1985) and lower than that reported by Elhag (1984). Ash in sorghum stover was similar to that found by Mohamed (1988) and higher than that reported by Elhag (1984). Ash in millet in this study was lower than

that found by Abusail (1992). Nitrogen free extract in sorghum stover was in line with the findings of Sulieman and Abdelrahim (1999) and Osman (1985), higher than that found by Ellis (1981) and lower than that reported by Elhag (1984). Nitrogen free extract in millet was higher than that found by Abusail (1992). Neutral detergent fibre in sorghum stover was in the range reported by Smith (1989). Sorghum stover had the highest CP and NFE and the lowest CF and MADF among straws indicating better composition and nutritive value unless other factors are involved as antinutritional factors. Millet straw had the highest fibres (MADF, NDF and CF) and low CP and NFE and is expected to be inferior in nutritive value compared to other straws. Sesame straw had the lowest CP and NDF and the highest CF and MADF was intermediate among straws and is expected to be inferior in quality compared to sorghum stover. Similarly, Van Soest (1982) found variations among straws in fibres which suggested variations in response to different treatments to improve the nutritive value. Further research is required to determine appropriate treatments for upgrading straws based on CP and fibres. The higher CP and lower CF in millet straw than sesame straw suggested a better nutritive value for the former.

However, NFE was less in the former. The lower CF in millet straw and NDF and MADF in sesame straw highlighted problems of fibre analysis in straws and results should be carefully interpreted. Similarly, Van Soest (1982) discussed fibre analytical problems and suggested that no single analysis protocol is satisfactory.

The variations in proximate analysis among parts of different crop residues were also reported by many workers (Phang and Vadiveloo, 1991, Mgheni *et al.* 2001) and were due to variations in parts structure and functions. Dry matter was high in all parts and did not vary greatly among parts and this was due to plants maturity and sun curing. Adebowale (1988) found that stage of harvest and maturity affected chemical composition and nutritive values. Leaves lowest fibres (CF, NDF and MADF) supported the higher leaves nutritive value compared to stems which had higher polysaccharides and lignin than leaves (Tainton, 2000). Similarly, nitrogen varied among straw fractions and was lowest in stems in maize stover and rice straw and

highest in leaves in rice straw and in panicles in maize stover (Mgheni *et al.*, 2001). The increased NDF and MADF in sorghum stover and

CF, NDF and MADF in millet and sesame straws from the upper to the lower part were similar to that reported by McDonald *et al.* (1994). This was attributed to nutrients transfer from stems and leaves to grains. The results suggested that it is better to divide straws into parts more than to leaves, nodes and internodes. It is also better to separate the lower part and use it for improving the nutritive value. The upper two thirds of straws can be fed together and supplemented with urea and molasses.

Whole plant with roots had higher CF, NDF and MADF and lower CP than WPO as reported by McDonald *et al.* (1994). This was because roots are more fibrous than stems. Ash was lower in WP than WPO. The results suggested that straws should be harvested and fed without roots as mainly used in the Sudan.

CONCLUSIONS

There were great variations in proximate analysis among crop residues and their fractions. Sorghum stover had the highest CP, ash and NFE and lowest CF and MADF and millet straw had the highest fibres. Fibres decreased from the upper to the lower part. Leaves had the best proximate analysis among fractions and straws should be harvested immediately after grains.

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التحليل التقريبي والألياف لمخلفات محاصيل الذرة والدخن والسمسم في ولاية القضارف بالسودان

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²مركز أبحاث الماعز، كلية العلوم الزراعية، جامعة الجزيرة، ص. ب 20، واد مدني، السودان

الخلاصة

تم تحديد التحليل التقريبي والألياف المختلفة في الأجزاء المختلفة من تبين الذرة الرفيعة (صنف أرفع قدمك) وتبين السمسم وتبين الدخن بجذور او بدون جذور، ولاية القضايف، السودان. قسمت النباتات الى أجزاء عليا، ووسطى وسفلي وأوراق كاملة. وجدت اختلافات كبيرة في تركيب الأتبان واجزائها وكانت منخفضة البروتين الخام ومرتفعة الألياف. كان لتبين الذرة أعلى البروتين الخام والرماد والجزء الخالي من النتروجين وأقل الألياف الخام والألياف الذاتية في الحامض المعدلة بين أتبان المحاصيل. وكان لتبين الدخن أقل الدهون والجزء الخالي من النتروجين وأعلى الألياف الذاتية في المنظف والألياف الذاتية في الحامض المعدلة. تقاربت الألياف الخام لتبني الدخن والسمسم ولم تختلف معنويا. الأوراق بها أعلى البروتين الخام وأقل الألياف. انخفضت القيمة الغذائية للأتبان من أعلى إلى أسفل.